Transactions

OF THE

Illuminating Engineering Society

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VOL. III.

JANUARY TO DECEMBER, 1908

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AT EASTON, PA.

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TRANSACTIONS

OF THE

ILLUMINATING ENGINEERING SOCIETY

VOL. III

JANUARY-DECEMBER

1908

Subject Index and Index to Authors

OFFICE OF THE GENERAL SECRETARY
29 WEST THIRTY-NINTH STREET
NEW YORK

SUBJECT INDEX

INDEX TO AUTHORS

The letter C indicates contribution; the letter D indicates discussion.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. JANUARY, 1908. No. 1

A meeting of the Council was held at the Electrical Club, 14 Park Place, New York, on Friday, January 10, 1908.

The monthly report on finances was given by the Secretary, and was received with approval by the Council.

A report of the Finance Committee followed, from which it was shown that the Society has, at the end of the fiscal year 1907, a surplus of a few hundred dollars, instead of a deficit as was originally feared.

The Advertising Committee gave a brief outline of the plans proposed to carry out in the work of advertising for the coming year, and was authorized by the Council to proceed along the lines indicated in the report.

A report of the Chairman of the Committee on New Sections stated that the plans for organizing sections of the Society in Los Angeles and San Francisco had not yet been successful.

A letter was read from the secretary of the American Institute of Electrical Engineers, extending an invitation to the Illuminating Engineering Society to be officially represented at the Memorial Exercises in honor of Lord Kelvin, which were to be held on January 12. Dr. C. H. Sharp, Dr. A. H. Elliott, Messrs. L. B. Marks, V. R. Lansingh, W. D'A. Ryan, and Arthur Williams were named as the representatives of the Society on this occasion, and the secretary was requested to send due reply to the secretary of the Institute.

The secretary read before the Council a communication in the form of a preamble and a set of resolutions bearing date of De-

cember 18, 1907, received from the Pittsburg Section and signed by L. J. Kiefer, Secretary, to the effect that the members of the Pittsburg Section had taken formal action to disband that Section.

A report of the meeting of the Executive Committee, held on January 2 to consider this question, was read, and was received with approval by the Council.

A motion was made, and unanimously carried, that Mr. G. B. Griffin, Vice-President of the Society, representing the Pittsburg Section, be appointed a Committee of One to investigate the matter of the discontinuance of the Pittsburg Section, and that the Secretary furnish Mr. Griffin with whatever correspondence, etc., he may require to accomplish his investigation.

The Secretary reported that eighteen applications had been received and had been duly approved by a committee on membership. Upon motion being made and carried, the applicants referred to were declared elected. They are as follows:

Allen, H. E., Electrical Testing Laboratories, Harrison, N. J.

Ashmead, John, Bureau of Lamps and Gas, Dept. Water Supply, Gas and Electricity, New York.

Bray, Walter J., Electrical Testing Laboratories, 80th St. and East End Ave., New York.

Brooks, W. T., Sterling Bronze Co., New York, N. Y.

Hunter, James F., Consolidated Gas Co., 4 Irving Place, New York.

Martins, W. F., Westinghouse Elec. & Mfg. Co., 11 Pine St., New York.

Promecene, Joseph H., Edison Elec. Illuminating Co., Brooklyn, N. Y.

Spencer, W. H., associated with I. P. Frink, 551 Pearl St., New York.

Wohlauer, Alfred A., 500 Fifth Ave., New York.

Beardsley, Daniel H., superintendent Citizens' Electric Co., Battle Creek, Mich.

Bowman, Claude A., House Electrician, Armour Institute of Tech-

Bowman, Claude A., house electrician, Armour Institute of Technology, Chicago, Ill.

Rogers, Gardner, 15-17 South Fifth St., Minneapolis, Minn.

Schweitzer, Edmund Oscar, Commonwealth Edison Co., Chicago, Ill.

Schwab, Louis A., president, Monarch Elec. & Wire Co., Chicago, Ill.

Nash, L. R., engineer, Stone & Webster, 147 Milk St., Boston, Mass.

Ten Eyck, W. F., General Electric Company, East Boston, Mass.

Thompson, G. L., General Electric Co., 1118 Witherspoon Bldg., Philadelphia, Pa.

Quackenbush, Charles H., Manager, St. Clair County Gas & Electric Co., East St. Louis, Ill.

CHICAGO SECTION.

A meeting of the Chicago Section was held on December 12 in the breakfast room of the Grand Pacific Hotel. At this meeting Mr. J. C. Cravath described the engineering work done in connection with the proposed lighting of Dearborn Street, Chicago. Mr. F. J. Pearson described the plans which had been made for the park commission for boulevard lighting in Chicago, and discussed the proper placing of flaming arc lamps.

A meeting of the Section was held at the Coliseum Electrical Show in Chicage, January 17. Chairman George C. Keech presided. The subject of the meeting was "The Gas and Electric Lighting of Apartments and Small Houses." The discussion was opened by Mr. George H. Jones, of the Commonwealth Edison Company, who read a description of the electrical features of the "House Electrical" which his company had erected in the Electrical Show to furnish to the public examples of electric lighting and the use of other electrical appliances. The discussion was participated in by Messrs. Albert Scheible, E. W. Lloyd, W. R. Bonham, J. R. Cravath, G. H. Stickney, Ludwig Kemper, J. M. Strasser, W. R. Putnam, H. V. von Holst, C. R. Gilman, C. A. Howe, and others. Members of the Northwestern Electrical Association, who were visiting the Electrical Show on that day, were invited to the meeting.

The election of officers for the Section for 1908 resulted as follows:

Chairman, J. R. Cravath.

Managers, Frederick J. Pearson, H. V. von Holst.

Secretary, George H. Jones, Commonwealth Edison Company, Chicago, Ill.

The attendance at this meeting was about 100.

NEW YORK SECTION.

A meeting of the New York Section was held on December 12, when the paper by Bassett Jones, Jr., entitled "The Relation of Architectural Principles to Illuminating Engineering Practice," was read and discussed. This paper is published elsewhere in this issue.

A meeting of the New York Section was held on January 9, when a paper by Dr. H. H. Seabrook, entitled, "Effects of Light Practice," was read and discussed.

At this meeting the following section officers were elected:

Chairman, W. W. Freeman.

Managers, W. Cullen Morris, Albert Wahle.

Secretary, Preston S. Millar, Eightieth Street and East End Avenue, New York city.

NEW ENGLAND SECTION.

A meeting of the New England Section was held on December 18, when a paper entitled "The Variables of Illuminating Engineering," by Professor William L. Puffer, was read and discussed. This paper, with the discussion, is published elsewhere in this issue.

At a meeting of the New England Section, held on January 14, the following Section officers were elected:

Chairman, J. S. Codman.

Managers, W. H. Blood, Jr., T. H. Piser.

Secretary, R. C. Ware, 24 West Street, Boston, Mass.

PITTSBURG SECTION.

A meeting of the Pittsburg Section was held on December 18, when a paper entitled "Fixture Design from the Standpoint of the Illuminating Engineer," by V. R. Lansingh and C. W. Heck, was read and discussed. This paper appeared in the November and December issues of the *Transactions*.

PHILADELPHIA SECTION.

A meeting of the Philadelphia Section was held on Decem- 20, when a paper by H. Clyde Snook, entitled "The Spectrum," was read and discussed. The author described the indulatory theory of light and showed the physiological effect produced by the colors of the spectrum. The paper was illustrated by lantern slides.

A meeting of the Section was held on January 17, when the following officers were elected for the ensuing year:

Chairman, C. O. Bond.

Managers, H. D'Olier, Jr., T. J. Little, Jr.

Secretary, J. D. Israel, Tenth and Chestnut Streets, Philadelphia, Pa.

ANNUAL MEETING.

The annual meeting of the Society was held in the rooms of the Electrical Club, New York city, on January 10. Dinner was

served at 6:30 p. m., and immediately afterward, President Clayton H. Sharp opened the meeting, and reports were read by the Secretary, by the Finance Committee, and by the Advertising Committee.

The chief point of interest was the report of the Finance Committee which shows that the Society has come out at the end of the year with a surplus of a few hundred dollars, instead of a deficit, as was originally feared by this Committee. The report, which shows that this surplus is due to the advertising in the Transactions, and makes a strong plea for an increase of membership, will be published in the next issue.

The Advertising Committee's report shows that about $800 have been received during the past year from the advertising in the Transactions. It was announced in this report that the advertising had been taken out of the hands of a paid solicitor, and placed in charge of an Advertising Committee of five, one member to represent each section of the Society. The Committee hopes by its management to make the advertising in the Transactions the place to look for the very latest developments along the lines of illumination.

President Sharp then gave a brief address on the affairs of the Society. Following this, the report of the Committee of Tellers was read, which announced that the following officers for the year 1908 had been elected:

President, Dr. Louis Bell.

Vice-Presidents, Arthur Williams, New York; C. E. Stephens, Pittsburg.

Directors, W. H. Gartley, M. K. Eyre, Bassett Jones, Jr.

General Secretary, V. R. Lansingh.

Treasurer, Dr. A. H. Elliott.

Dr. Sharp then introduced the new President, Dr. Bell, who responded with an optimistic address, outlining his reasons for holding that the Society has a great future before it, and stating that it was essential among other things, to increase rapidly the membership. There followed a broad discussion on general affairs of the Society, after which the meeting adjourned.

Obituary.

J. A. LEWIS.

J. A. LEWIS was born on a farm in Ohio, where he spent his boyhood. In early childhood he exhibited a great fondness for acquiring knowledge. He is remembered as a youth who excelled all others in his studies at the village school. At the age of fifteen he was thrown upon his own responsibilities, and he went to Kansas where he worked on a farm, taught school and attended the state agricultural college. Here his leadership and mastery of his studies easily marked him as one of the ablest members of his class. After his graduation from the Kansas Agricultural College he entered the University of Michigan, from which he later received the degree of civil engineer. For the remaining nineteen years that he lived he was engaged in engineering work and resided mainly in Chicago. He was a hard worker and constant student, who acquired a wide range of knowledge. With quiet habits and modest manners he lived a simple life, and suffered much and long with an affiiction of which he never complained.

JOSEPH M. MAHONEY.

JOSEPH M. MAHONEY was a graduate of the Massachusetts Institute of Technology, of the class of 1897, in electrical engineering, and was identified with the electrical profession until his death, August 21, 1907, at thirty-three years of age. After graduating from the Massachusetts Institute of Technology he was employed by the Boston Elevated Railroad in some of the power houses, having in charge the electrical apparatus of the various plants. He was then made superintendent of the construction department of an electrical concern for deriving power from the wind, by means of windmills, and using storage batteries for the storage of current when the wind was strong, and for delivering current when there was no wind. From the above concern he entered the wire department of the city of Boston as inspector, where he remained for nearly eight years, until his death. He was always upright and honorable, and was

held in the highest esteem by his fellow workmen, colleagues and acquaintances.

AUGUSTINE SHEPPARD MALLORY.

Augustine Sheppard Mallory, who passed away the morning of August 9, was in every best sense of the term a self-made man. He was born in Charlotte, N. C., April 26, 1871, which place had hardly then even commenced to feel relief from the stress of civil war. At an early age he took service with Leddell & Co., of Charlotte, and in 1891 he removed to Philadelphia, and shortly thereafter entered the service of R. D. Wood & Co., acting in the capacity of field engineer. Later on he became attached to the engineering division of the Mutual Gas Light Company, of the city of New York. He later became attached to the engineering staff of Bartlett, Hayward & Co., of Baltimore, and at the time of his death he was superintendent of construction and resident engineer of that corporation. In 1896 he was married to Miss Gertrude A. Wunder, of Germantown, who survives him, as does his father, Wm. A. Mallory. He was widely and favorably known in the gas works construction circles of the country.

W. J. PHELPS.

W. J. Phelps, vice-president of the Phelps Company, Detroit, Mich., died at Grace Hospital, Detroit, Mich., at half-past three, Tuesday afternoon, September 3. Mr. Phelps was one of the best-known lamp manufacturers in the country, and a wide circle of friends and acquaintances will join the bereaved family in mourning his demise. He was a man of peculiarly lovable disposition, made friends in every walk of life, and the genuine evidence of sterling character with which he always impressed even a casual acquaintance endeared him to those who had the opportunity of becoming well acquainted. William Joshua Phelps was born in Elmwood, Ill., November 19, 1866. He was a graduate of Knox College, Galesburg, Ill., and was a member of the Illinois Delta of Phi Delta Theta fraternity. He was an electrical engineer and inventor. The best-known and most useful of his inventions was the "Hylo" lamp, which he manufactured in its various forms. Mr. Phelps is credited with being the originator of the turn-down lamp art, which is proving to be an extensive business. He was also the inventor of the motorless flasher, which

has proved to be of great use in the electrical advertising field. He was a member of the American Institute of Electrical Engineers, the American Society for the Advancement of Science, the Illuminating Engineering Society and the Detroit Engineering Society. He is survived by a widow and two children, his father mother, and a brother and sister. Mr. Phelps had undergone a radical mastoid operation at Grace Hospital several weeks ago, and was in a fair way to recover. On August 31 he complained of severe pains in his head, and during the morning fell into a coma, from which he never aroused. The cause of death appears to have been inflammation of the membranes surrounding the brain. The interment was made on Friday, September 6, in Springdale Cemetery, Peoria, Ill.

THE RELATION OF ARCHITECTURAL PRINCIPLES TO ILLUMINATING ENGINEERING PRACTICE.[1]

By Bassett Jones, Jr., *Member*.

(1) Successful illumination of structures making an appeal to the sense of beauty requires a more or less developed sympathy with the aesthetic qualities of the design. I hope to make the importance of this statement reasonably evident. But before we attack the subject proper, I think it necessary to come to some clear understanding of what is meant by the aesthetic qualities of a design.

(2) The engineer has, unfortunately, little opportunity of learning to appreciate beautiful things, and his limitation in this regard often leads him unduly to accent what he terms "practical considerations." He sometimes forgets that there is an essentially pragmatic purpose at the basis of all true art, and that the aesthetic emotions are increasingly important as man reaches the higher stages of mental development.

(3) We must remember that the ancient civilizations, by a path of almost pure intellectual evolution in philosophy and aesthetics, attained a plane of intelligence in some respects higher than that reached by the most advanced of modern peoples. To the early Greeks, improvement in artistic method was of as great practical importance as any advance in scientific discovery is to ourselves. The word "practical" is essentially relative in its meaning, and there is grave danger in giving it but a one-sided application. The downfall of the ancient races was due, fundamentally, to a disregard of any but abstract principles. But whether a failure to recognize the importance of these same principles will be equally destructive, only the pendulum of history can decide.

(4) My chief purpose in this paper is to show that the illuminating engineer who considers only the scientifically practical side of the profession is necessarily doomed to ultimate failure, for he will not be able to obtain the recognition that the importance of his work deserves. Our Society and our profession are young, and it seems to me that a word of warning is needed, or ill-

[1] Read before the New York Section, December 12.

directed enthusiasm is likely to sweep us off our feet. We should study the limitations under which we must work, and be guided by them.

(5) To attempt to plunge at once into a discussion of architectural principles, without any consideration of their basis and genesis, I believe would be quite useless. I propose, therefore, to ask your attention for a few minutes while we trace the meaning and nature of "aesthetic."

NATURE OF "AESTHETIC."[1]

(6) When we view a magnificent and artistic composition for the first time, it produces in us a very delicate poise between the two extremes of novelty and recognition. In many ways it is the same as more familiar objects, and yet there are characters about it that are quite new. It challenges our attention as the hunter challenges the purely organic attention of the young fawn, and the whittling down of this contrast between repulsion and attraction, or curiosity, if you will, may be carried as far as the artist's skill permits.

(7) But this is not all. The challenge of novelty is merely the entering wedge. The attention, aroused to a high pitch of nervous excitement, must find its release in a discharge one way or another, and if the balance is in favor of interest, the result will be a pleasurable emotion. What then are the emotions which the object of beauty must arouse?

(8) First, and primarily, sympathy. We must find embodied in the object the expression of our own ideas of appropriateness and fitness. There is a bond of temperament between the artist and ourselves. He has expressed an idea with which we heartily agree. The artist may be original in his conception only so far as his public can follow. "Originality in art," says Baldwin, "as in everything else, is an affair both of individual endowment and thought, and of social recognition and confirmation."

(9) Sympathy, like any other emotion, may be either organic or reflective. Organic or innate sympathy passes into reflective

1.—The word *æsthetic* is used here in its full meaning of implying the fundamental nature of the hyperlogical judgment—a judgment of feeling rather than of knowledge, where consciousness of the contrast between self and object is lost in contemplation. It is inadequately expressed by the saying "He had completely forgotten himself," as in the presence of a beautiful painting. To those whose interest leads them to the desire for further information on the subject I would suggest a study of the chapters on adaptation, sympathy and emotion in "*Mental Development*" by J. Mark Baldwin, and the "*History of Aesthetic*" by Bosanquet. In Ladd's "*Psychology*" (large edition) there is a very suggestive chapter on "*The Aesthetic Emotions.*"

sympathy when the relation of the subject experiencing the organic emotion to the stimulus becomes a fact for knowledge. Thus, the mere presence of a beautiful object produces appropriate pleasurable reflexes in the form of heightened nervous vitality, and the result is an organic attraction toward the source of the pleasure-arousing stimulus. This is the purely organic part of the aesthetic sympathy. When, however, there is a distinct effort made to increase the stimulus by appropriate volitional activity, either through imagination, or by actual objective construction, sympathy has become conscious or reflective. Imagination always precedes the objective construction, for it is only by imagination that we can conceive how the pleasure-giving object may be improved upon so as to heighten the emotional reflexes. Imagination, however, proceeds through a persistent and repeated combination of the materials of memory by the process of imitation. Memory, and therefore an extensive familiarity with objects of beauty, plays a very important part in the development of the aesthetic sense.

(10) The culture of the imagination is of great importance for the appreciation of the beautiful, both from the point of view of the artist and the beholder. The artist is peculiarly sensitive to orders of form and color. These provide the basis for the operation of his imagination, precisely as certain orders of masses and movements furnish the stimulus for the theorizing imagination of the scientist. He then seeks to give material reality to his ideas through the best means at his command, and we, his public, must again appeal to memory for its development and meaning.

(11) Consider the exquisite congruity and harmony of ideas in the following passage where Shakespeare draws so finely upon his experience of similarities in feeling:

> "Oh, it came over me
> Like the sweet south upon a bank of violets
> Stealing and giving odors."

(12) Where could imagination find a better means of conveying the emotion aroused by sweet music! And what possible meaning could the thought have for one whose memory and imagination failed him in filling the picture?

(13) The novelty of a new aesthetic experience verges closely upon similarity, and the degree of similarity of the new arrangement to old and pre-established orders must be carefully accented

if the result is not to be productive of painful rather than pleasurable emotion. A too evident imitation of familiar historic objects is at the same time to be avoided, for there is then no challenge to the attention and the feeling of recognition is at once terminated. A very interesting example of this form of suspended recognition is found in the wonderful finale of "Tristan and Isolde," where the sense of attunement is strangely puzzled by the apparent lack of tonic relation between the chords. The musically ignorant man finds nothing but a meaningless jumble of sounds. His memory fails him completely and the strangeness of the sounds repel him. On the other hand, the attention of the musician is strongly aroused. He tries to fit this new experience to memory after memory. Each chord is familiar, yet the harmony is strange. His imagination runs riot, until with the closing measure his interest is satisfied by a marvelous resolution into the motives of bliss and peace.

(14) This necessity for finding a similarity, an old sensation of pleasure to match, through which the novel developments may be adapted to our present stock of aesthetic memories, has given rise to the schools and orders—unitary systems by which the new in art may be apperceived. There is a fundamental similarity in all the features of each period, which arouses a sense of rest. The conception is not upset by widely sundered feelings. We are not called upon to apperceive two such different objects as a wrought-iron bracket on a Louis Quatorze panel. But the readiness with which the harmony of the design will be appreciated is much a matter of previous training. The artistically ignorant man would not notice any incongruity—nor would he notice the congruity.

(15) The emotions of peace and rest are directly aroused by harmony of proportions, and these, too, find their organic basis in the pleasure-pain contrast, passing into the feeling of security or danger. Familiarity here also plays an important part. We feel at home amid scenes for which our memory possesses the key.

(16) The emotion is again the feeling of the reflex organic activity which experience instinctively furnishes as appropriate to the occasion. Continued experience of this contrast between safe and unsafe construction is the basis upon which the imagination builds the aesthetic qualities of proportion, but the genesis

of the emotion is greatly obscured and complicated by overlapping feelings aroused by other qualities of the object.

(17) Proportion may also be deduced from the interest which the object holds for us. The meaning of an object which has no evident order in its arrangement defies detection, and repels rather than attracts the imagining activities. It is merely a chaos of conflicting terms. But if the attention is to be sustained—and this is essential for the aesthetic feeling—the point of attraction must not be too evident. Its novelty must be sufficient to resist immediate memory conversion. It must compel a rearrangement of our store of experiences.

(18) The organic analogue of the feeling of proportion is found in a concordant and orderly change in the somatic or muscular reflexes which the stimulus arouses. There is no sense of disruptive and violent alteration. Thus, the pleasure which an easy curve excites is largely due to the sense of ease and abandon with which the eye muscles follow its contour; while, on the other hand, the right line demands a certain amount of muscular effort and constraint.

(19) So the pleasure of the dance comes fundamentally from the ease and restful order in which one movement follows another. The emotion aroused borders closely upon the aesthetic, but it is difficult, if not impossible, to draw a line and say "here ends mere organic pleasure and begins aesthetic emotion."

(20) The feeling of the beautiful, however, is never merely the feeling of the agreeable. "For the perception of the beautiful depends on three things: (a) pleasure attaches to form and not material of sensation, (b) the object must be recognized as implying relations not immediately present, (c) there must be some concordant series or composite of agreeable objects. A single tone may be sensuously agreeable; an aria or harmony (series or composite) is necessary to arouse aesthetic feeling. A single color of moderate intensity may give purely organic pleasure, but it takes an orderly arrangement of shades and colors to tickle the imagination."[1]

(21) This very inadequate and sketchy outline may perhaps make clear to us the basis on which the feeling of the beautiful is formed. Evidently, it gathers into itself the end and aim of every emotion of which organic beings are capable. In all walks

1.—"*Psychology—The Aesthetic Emotions.*"—Ladd.

of life it is the aesthetic that has the last word. The merchant contemplating the success of his schemes, the scientist contemplating the progress of his investigation, the artist contemplating his creations; in all we find expressed the feeling of beauty. We may even appreciate the poet's ecstasy when he sang:

"Beauty is truth, truth beauty."[1]

(22) So much for the abstract. Beauty is divided into kinds, precisely as the means of expression are themselves divided, and it is our purpose this evening to discuss briefly the beautiful in architecture. To that end we shall now apply our three postulates above, and attempt to show how they give rise to the principles of architecture.

THE PRINCIPLES OF ARCHITECTURE.

(23) The impulse to avoid injurious or painful stimuli and prolong pleasurable stimuli, is the foundation of all organic activities. With the rise of consciousness and the development of volition this impulse becomes, we may almost say, the fundamental purpose in life. In the higher reaches of mental development this purpose makes itself evident in an almost infinite variety of attempts so to modify the environment that its pleasure-giving stimuli will be greatly in preponderance over its pain-giving stimuli. Any object that furthers this end is termed "useful," whether that object be a lead pencil, or the canvas of a master. This, the utilitarian purpose, is the basic actuating principle of all our beneficial activities. Distorted and misdirected it also becomes the fundamental source of evil.

(24) Architecture, then, primarily, has for its purpose the provision of structures designed to furnish protection from the vicissitudes of climate, and the fulfillment of this purpose alone is sufficient to give pleasure of a very elementary sort. The requirement of familiarity then demands of the architect that his structures shall so appeal to memory as to make evident its secondary purpose. The pleasure is not in the puzzle, but in its solution. The mind instinctively asks, "What is the thing for?" and unless the answer is forthcoming, no amount of grace or ornament can overcome the ensuing feeling of repulsion. We find ourselves in a strange place, and the ruling impulse is to escape.

1.—So far, illustrations have been drawn from fields removed from the subject of this paper, to indicate the broadness and generality of the principles discussed.

(25) The tendency to make every useful object more pleasing is, as we have noted, fundamental in the imagining activities of the mind, and there naturally results an effort so to fashion the object that while it still serves its primary utilitarian purpose it will stimulate the senses in a manner conducive to the greatest amount of pleasure possible. We have seen that this effort finds its highest expression in the form known as aesthetic, and that the perception of the beautiful makes three demands upon the object:

(a) The sensations aroused by the object shall be of such a form that they may be readily responded to by the organism in its

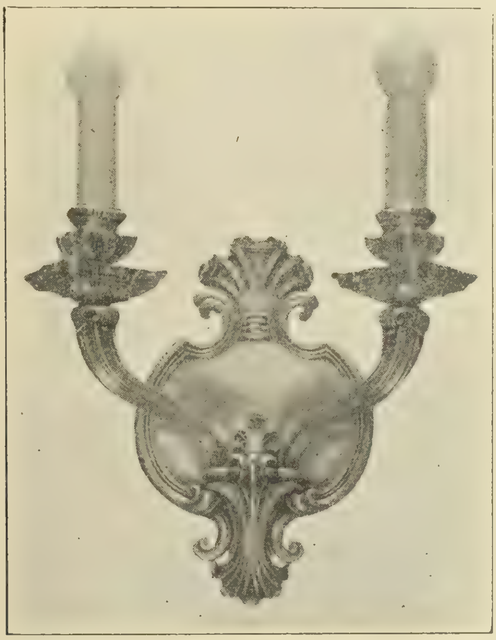


Fig. 1—Old English Wall Bracket.

habitual manner, and, therefore, there must be no discontinuity or suddent alteration in their flow. If discontinuity occurs, the reason for it must be evident, and natural. Some attractive provision must be made, often by means of appropriate ornament, so that the mind can readily bridge the gap. Take, as an example, the old English wall bracket shown in Fig. 1. Its great charm lies in an exquisite harmony of curves. The lines generating each part sweep into one another without break or raggedness. The eye follows its contours with pleasurable ease. Beauty has been added to usefulness by conceding to the simple demands of the visual sense. On the other hand, we have in Fig. 2 a discon-

tinuity in lines cleverly bridged by decorative ornament. So the architect, in designing a building, must contrive its featural lines so that the eye can follow them and the mind perceive them in a natural and unconstrained manner.

(b) The object must be sufficiently suggestive in its aspect to demand some effort of the imagination in discovering its full

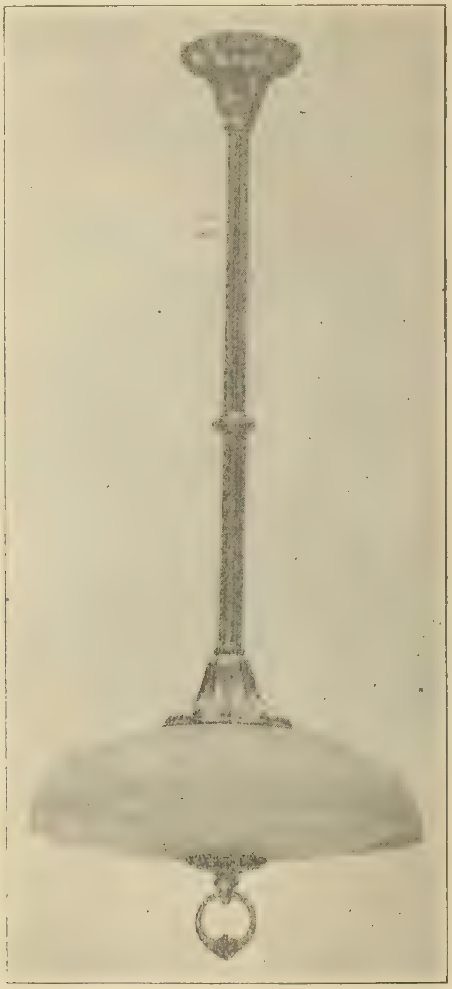


FIG. 2.—SHOWING CLEVER USE OF ORNAMENTS.

meaning and relations to its environment. The interior shown in Fig. 3 finds, perhaps, its greatest aesthetic effect in its religious symbolism. To those to whom the appeal can be made it suggests the strength and mysticism of the early Christianity. Its feeling is tense with the exhalted religious spirit of its builders. It has a story to tell, and is successful because it is full of imaginative suggestion. It carries us beyond its bare objective presence to

FIG. 3. -WESTMINISTER ABBEY CHOIR, SHOWING LIGHTING.

a realm of ideal and contemplative construction, that transcends the limits of actual experience.

(c) The several parts of the object must be in harmony. This requires that the parts be different, while at the same time the perception of each part must lead naturally (with smooth organic flexes) to the perception of the next. The relations between the parts, and the relation of each part to the whole must be reasonably evident. "Harmony," says Hegel aptly, "is a system of relations all of which are interior accord." The relation of each part to its corresponding element of perception in the mind of the beholder has its physiological analogue in the train of sensation which it arouses. If the sensations clash, then the perception of disorder becomes evident and the object repels rather than attracts. The question of proportion here becomes predominant.

(26) The requirement, that the several parts of the object or building shall arouse concordant sensations, demands that the relations between the several parts of the object shall be apparent. The technical name of this character is "proportion." Its importance cannot be over-estimated. And we find throughout ancient classical architecture an evident attempt to carry it to its logical extreme. No artificial object was considered too insignificant to express some definite proportional relation. Not only individual buildings, but whole cities were laid out so as to present a harmonious appearance. The City of Athens, with its Acropolis, was a magnificent example of the application of the law of proportion. And similarly in painting, the effort to achieve the fullest expression of harmony in color and tone reached its climax in the work of Michael Angelo.

(27) We have earlier (§§ 15, 16) touched upon the sense of structural proportion aroused by experience with safe and unsafe construction, and it only remains for us to draw conclusions in the light of our study of the memory coefficient. We must remember that the use of steel, and similar materials requiring slender proportions, is of very recent occurrence. So far is this true that any degree of study of the aesthetic features of buildings will produce a great superabundance of feeling for the heavier construction of wood and stone. And the memory coefficient will naturally produce a sentiment in favor of heavy proportions even where steel is used. The time is by no means ripe for a deliberate use of steel as steel, unless some means is adopted to increase

its apparent weight. This requirement, of course, does not occur in subsidiary construction, where there is historic precedent, although this must not be taken as a reason for ignoring the structural proportions of the environment. To take an example, a lighting fixture must be proportionately heavy, if it is to be employed in a room of massive construction. Otherwise the feeling of balance will be disturbed. This, I may remark in passing, is a rule that has not been duly considered in some recent discussions of fixture design.

(28) A simple example serving to illustrate the basic organic principle of proportion is given in Fig. 4. The square there shown has a certain proportion between its sides due to the fact that their relation is of the order unity. There is, however, no appeal to the attention because the case is one of mere repetition,

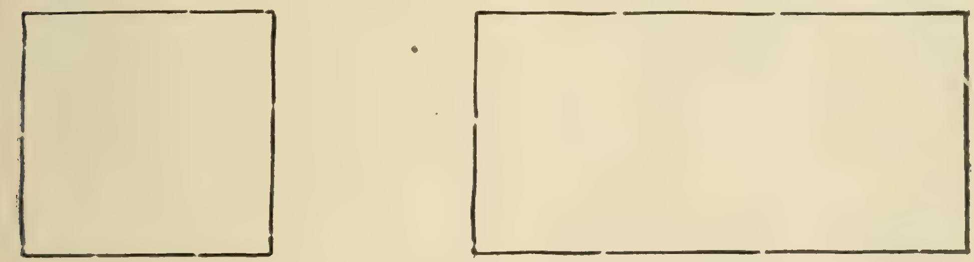


FIG. 4.—EXAMPLE ILLUSTRATING THE BASIC ORGANIC PRINCIPLE OF PROPORTION.

and possesses no novelty. A single glance of the eye is sufficient to determine all its possibilities. The imagination remains dormant. But let us lengthen two of the sides so that their relation to the remaining sides is of the order two to one. At once we perceive the difference. There is an alteration in the form of the visual sensation as the eye passes from one side to the next. The attention is at once challenged, and curiosity is aroused. But there is no confusion between the perceptions of any two adjacent sides and the mind readily adapts itself to the order of change.

Now turn to Fig. 5. This interior at once appeals to the attention, and for the reason noted above. The featural lines form a definite proportion, the one with the next following. A scaled section of the building would make this evident at once. The enclosed spaces are also in proportion to each other and in proportion to the lines bounding them. Where the eye is likely to find any abruptness, ornament has been well used to detain the atten-

tion and make the transition more gradual. And this brings us to the last point we have time to discuss—the use of ornament.

(29) The genesis of ornament has its root in the very human characters of conceit and pride. It appears first in the rings and feathers of the savage and in the war paint of the Indian, expressing the desire to improve and accent the object of beauty, or

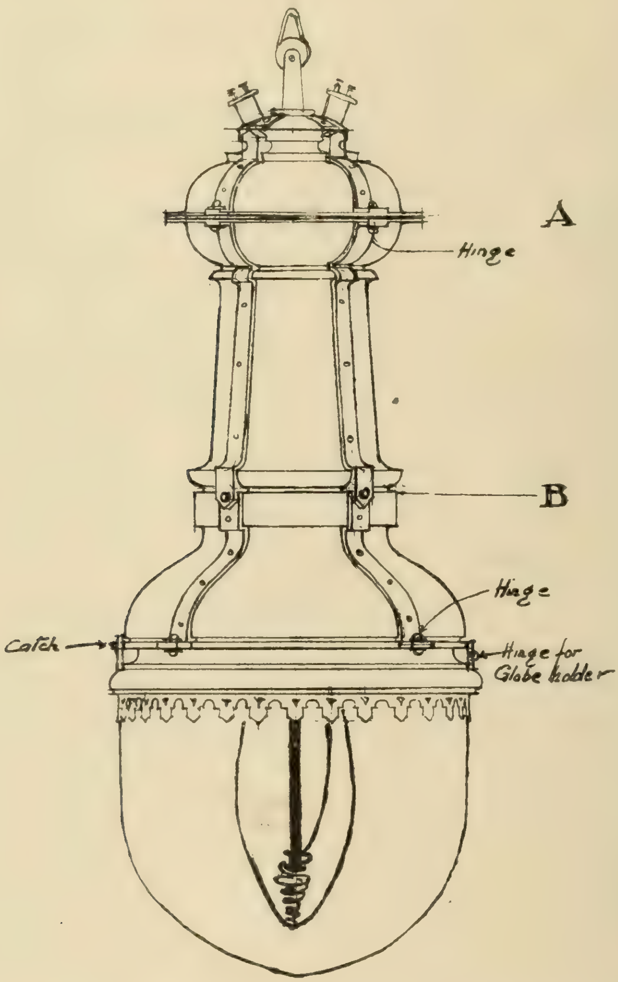


FIG. 4A.—APPLICATION OF LAWS OF PROPORTION TO ARC LAMP CASING.

ferociousness, that appeals to the elemental mind. But we, whose trained intellects can grasp the true worth of proportion, require no bangles or paint to attract our attention to the naked beauty of the human form.

(30) As Ruskin has expressed it, "The works of God are perfect." They are so admirably fitted and proportioned to the fulfillment of their purpose that ornament could only serve to mar

their beauty. But human effort and skill are so far limited that the deed is never the perfection of the thought. The meaning is always clouded by the ineffectiveness of its presentation.

(31) This lack of unambiguous expression of the function of each part of our utilitarian construction compels the use of orna-

FIG. 5.—ST. SULPICE NAVE, SHOWING LIGHTING FIXTURES SUSPENDED FROM ROOF.

ment as a means of emphasis and as a sign of the use to which each part is put; for, parts differing in function must differ in appearance. It is not evident, then, that in the proper or improper use of ornament is the success or failure of the whole design. And it is also evident that the slavish use of decoration is but a con-

cession to bad proportion and lack of expressive ideas. Ornament, not to be vulgar, must be handled with most exquisite taste and sense of propriety, for in ornament more than in anything else we may read the mental standards of the period. An intimate knowledge of its history and use is essential for its proper treatment. Fig. 6 is inserted as an example of the perverted use of ornament to hide the lack of constructive lines.

THE ARCHITECT AND THE ILLUMINATING ENGINEER.

(32) The principles of architecture are, we now see, no mere whim on the part of the designer. They are as deeply rooted in

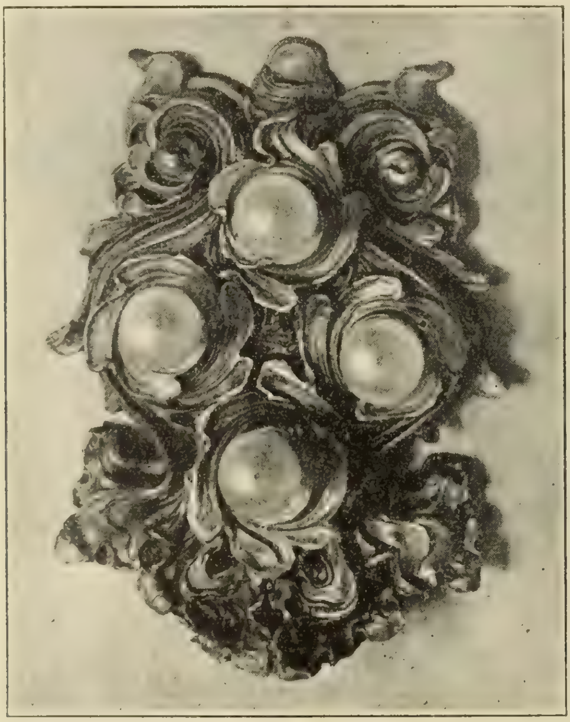


Fig. 6.—Example of Illegitimate Use of Ornament.

a basis of fact as are the principles of natural philosophy. The conceptions of good architecture are subject to the same order of constraint that limits the postulates of science.

(33) I have considered it necessary to devote so much of our time to this inadequate and sketchy outline, because I have noted, on the part of many contributors to the literature of illumination, a disposition to decry and criticise the limitations which architects place upon their work. They do not seem to realize that the beauty and effectiveness of good architectural construction, both

from aesthetic and utilitarian standpoints, depend upon a strict adherence to the principles outlined above, and that the feeling of the design dependent, as it must be, upon historical precedent is bound by centuries of usage to certain effects of color and light which have become established because of their appeal to the sentiments aroused by pleasurable visual perception. The business of the illuminating engineer is to modernize old methods of illumination without destroying them. If we are to discard tradition altogether, then we may as well abandon the architecture of the past, and ignore its influence. This, as I have tried to make evident, is impossible, if not on aesthetic grounds, then on physiological grounds, and to deny its demands would be suicidal. "Habit," says James, "is the great fly wheel of Society." Any sudden alteration in its movement would only serve to smash the whole machine. Change can only be brought about by infinitesimal alterations in its progress. The illuminating engineer, who imagines that he will be permitted to introduce anything radically new into the illumination of buildings possessing historic feeling, is doomed to disappointment. Rather is it his duty to maintain and conserve that feeling in spite of modern appliances and means.

(34) The "feeling" of the design must be carried out consistently even to the last detail of the fixtures. It is the duty of the archictect to see that this is done. His conception of the whole arrangement must include the lighting, for, as he sees it "in his mind's eye," so must it be seen objectively. The light that must be provided, its tone, its intensity, its quality, is a feature of his mental conception, and it is this ideal illumination that the engineer must seek to approximate. Of course, he can only hope to do this when he, too, is able to see the design as the architect sees it, and not through the eyes of the illuminating specialist alone. The engineer must be able to discern where direct or indirect illumination is required, and the kind of fixtures associated historically and aesthetically with the general design, by means of which he must obtain the proper results. For instance, examine Figs. 7 and 8. Note the absolute harmony both in proportion and detail, denoting throughout the expression of a single ideal. No other scheme of illumination, and no other style or type of fixture could have been used without marring the entire effect. Such illumination is good illumination. The resulting distribution may not be perfect from the engineer's standpoint—but then his stand-

point is itself imperfect if he fails to consider just the limitations imposed upon him by the design. Illuminating engineering is not a matter of light distribution—it is a matter of suitable lighting, and the conditions determining what is suitable are just as different as any two designs are different—no more, no less. Does the architect consider a building unsuccessful unless each part of it is laid out according to the laws of construction? Not a bit of it! The laws of construction are an after-consideration—a means of checking the proportion to see if, after all, it is safe. So, too, the illuminating engineer must use the laws of distribution, not

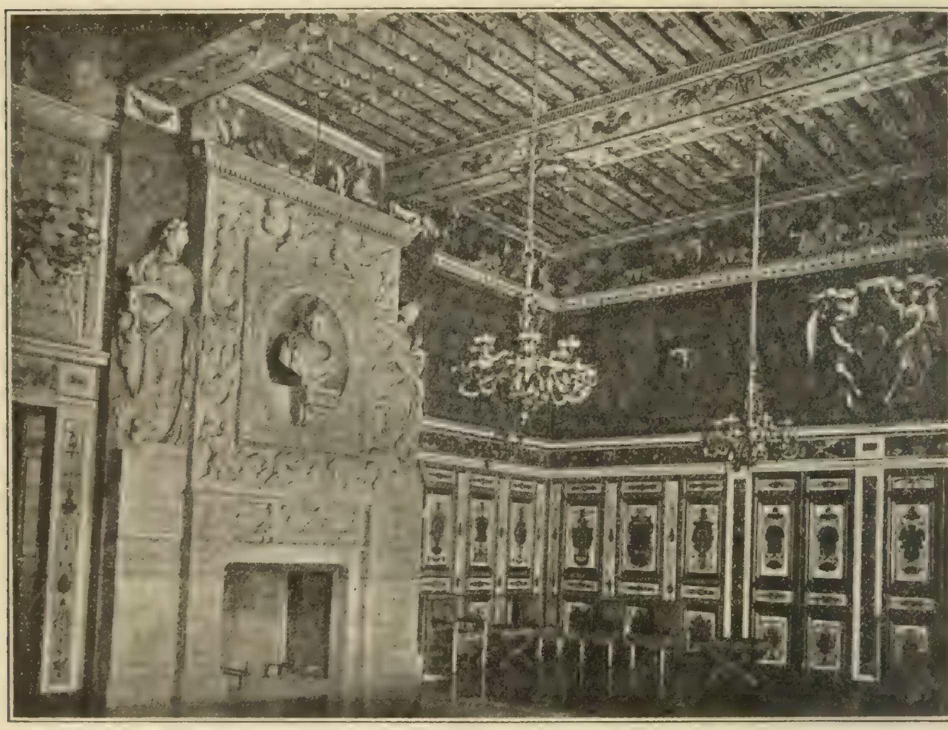


Fig. 7.—Salon des Gardes, Fontainbleau.

as a method of determining what the distribution shall be, but as a means of adapting the lamps to the distribution required. It is not a question of foot-candles; it is a question of how much light is needed. And it is more often a question of quality than quantity.

(35) You will say that foot-candles and quantity of light are one and the same thing, but I assure you, that from the architect's point of view, they are quite different. Two lamps giving an identical quantity of light may give entirely different quantities of illumination. The room shown in Fig. 9 is furnished with a very small quantity of light, but with ample illumination.

The same quantity of light, if used in Fig. 7, assuming the rooms to be of the same general dimensions, would give practically no illumination even if the general coefficients of reflection were in both cases identical. For what we see is, as the early part of this paper sought to make clear, not only what our optical nerves bring to the visual centres, but, in addition, a vast amount of suggestive material aroused to consciousness through the associative brain tracks.

(36) This associative material, with the actual sensory matter, together make up the perception which is conceived as an idea.

FIG. 8.—SALLE À MANGER, GRAND TRIANON.

The idea tends to find itself realized or embodied objectively, and this tendency toward the habitual, or normal, conversion of the idea, is sentiment. In art, sentiment is defined objectively as the "feeling" of the design, and where the sentiment is not realized we say that the design is out of keeping, and, in so far, defective.

(37) How, then, is the illuminating engineer successfully to cope with his problem and advise with the architect as to the best means of achieving results, if the engineer cannot appreciate and understand the architect's viewpoint? Manifestly, it is impossible for him to do so.

(38) It seems, then, that a very important, if not essential, feature of the engineer's preparation is a study of the history of illumination[1] and its relation to architectural design. He must make himself intimately acquainted with the means, methods and results of earlier work, and good work it is where any attempts were made to obtain adequate and suitable lighting. We must not think, because we alone can formulate and employ the laws governing the distribution of light, that good lighting has not been earlier achieved by empirical methods. We are simply in a

FIG. 9.—A COLONIAL ROOM. NOTE THAT A CENTRE CEILING FIXTURE WOULD RUIN THE EFFECT.

position to do more efficiently what the masters have done in spite of their manifest limitations.

(39) This branch of illuminating engineering is unquestionably an art, and only a science in so far as an art is scientific in its method. The illuminating engineer who hopes to cope with the lighting features of architectural problems, must be familiar with architecture, and particularly with the use of color in decoration; for as we well know the aesthetic value of color arrangements depends on extreme nicety of contrast, and color contrast

1.—I cannot do better than advise the study of that most important work, "*Histoire du Luminaire*," by Henry D'Allemagne, a work unfortunately out of print, a copy of which is accessible in the Avery collection in the Library of Columbia University.

is very susceptible to variations in tone and intensity of light, particularly at the low intensities very generally desirable from an artistic standpoint.

(40) The question as to the proper location and arrangement of fixtures, then, resolves itself into the question as to the way in which the design is to be seen. The proportions of the structure, its constructive lines and the points where they originate and end —these are to be brought out in relative prominence, and to do this properly the individual responsible for the lighting must be able to discern and select these features and modify his illumination accordingly. Take as an example the trefoil Gothic arch

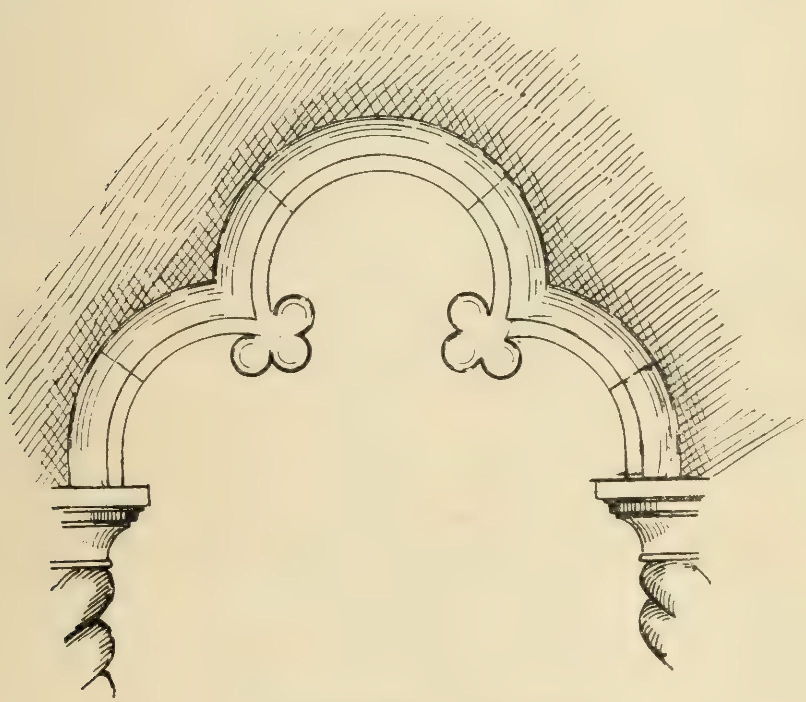


FIG. 10.—TREFOIL GOTHIC ARCH.

shown in Fig. 10. This, we will assume, by its importance in the structure, requires to be seen in its entirety. It is not sufficient that one segment or even the two lower segments be brought into prominence. It is demanded by the nature of the problem that the light so fall upon it that the eye shall be capable of tracing its outline from one abutment to the other, and if this cannot be done there will result a feeling of insecurity and of incompleteness. The problem, then, becomes one of so locating the lights that this result be accomplished. It is even advisable that the spring line of this arch be relatively brighter than the spandrel

spaces, and this may be effected by the suitable use of color or shadows.

(41) An example of the illumination of ornament is shown in Fig. 11. Suppose it is desired to place a single lamp at the centre of the relief ornament used to decorate the opening of a small arch such as might be found in the dome of a rotunda.

(42) If the rotunda is to achieve its full effect, its decoration must be brought into prominence, and to accomplish this the lamp must be so located that, in addition to its work of furnishing light to the space below, it will bring out the principal generating lines of the decorative relief, that is the ridges of the cockle in this particular example. In other words, the curve A—B—C of each member must be thoroughly lighted for its entire length.

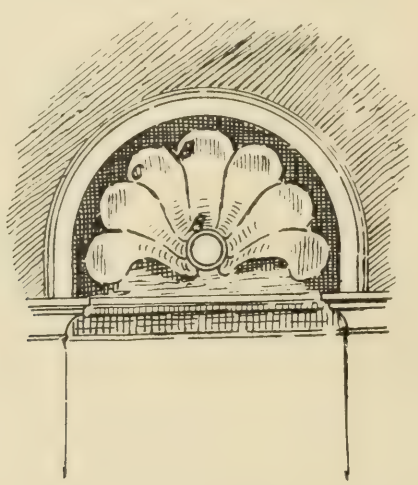


FIG. 11.—EXAMPLE OF THE ILLUMINATION OF ORNAMENT.

The architect, if he is alive to the necessities of the problem, will have allowed for this feature by giving a concave form to the ornament, and by deepening the space between it and the arch line. The arch line will itself project beyond the ornament sufficiently to receive a proper illumination, and a projecting mould serving to mark this line would also serve to cast a shadow on the spandrel and so bring the arch into added prominence. If the architect has failed to allow for these requirements in his design, or if the exigencies of the occasion have prevented the projection of the arch, then the lamp must itself project sufficiently to accomplish the result, and in that case the spandrel would receive more light than its importance deserves. It is, in fact, impossible properly to light a design that has not been conceived as illuminated and suitably adapted therefor.

(43) These examples may serve to illustrate the exquisite finesse and detail of consideration with which both the architect and the illuminating engineer must approach the problem of artistic lighting. Ignorance on either side may be productive of most disastrous results. There is a staring example of the misuse of artificial light in the ceiling of one of our large music halls, where the relief decoration has been absolutely ruined by placing lamps where they can only cast shadows on those portions of the design that require to be brought into accentuated prominence; nor is this an uncommon defect in many of our handsomest buildings.

(44) In earlier discussions[1] the writer has brought forward a few suggestions as to general method, and it is unnecessary to

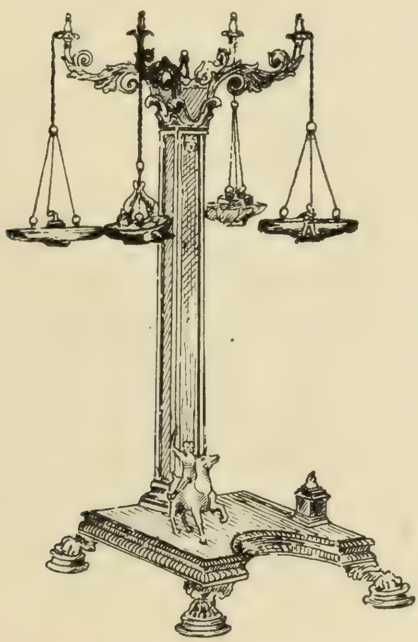


FIG. 12.—OLD ROMAN LAMP BEARER.

repeat those matters at this time. He does desire, however, to present one or two examples of the use of historic precedent in illumination.

HISTORIC PRECEDENT IN ILLUMINATION.

(45) Probably the earliest account of any method of artificial illumination occurs in Homer's account of the palace of Ulysses. Pliny describes a Phoenecian banquet hall as illuminated by fix-

1.—*Electrical Review*, Vol. LI, No. 11, September 14, 1907. *Transactions of the Illuminating Engineering Society*, Vol. II, No. 6, June 1907; Vol. II, No. 8, Nov. 1907.

tures consisting of golden statues bearing in their hands massive bowls filled with olive oil, on which floated blazing wicks. It would hardly be possible to conceive a more effective method of lighting a space in the rude and massive architecture of that period. Here is, indeed, a splendid suggestion for the illumination of a great foyer, or forum of bold design.

(46) The archaeologist has presented us with an almost infinite variety of Roman lamps and stands of exquisite design. Fig. 12 is a lamp bearer in bronze, now in the Naples Museum, which shows that the so-called "drip-saucer" of modern candle fixtures has a decorative precedent, even antedating the use of the

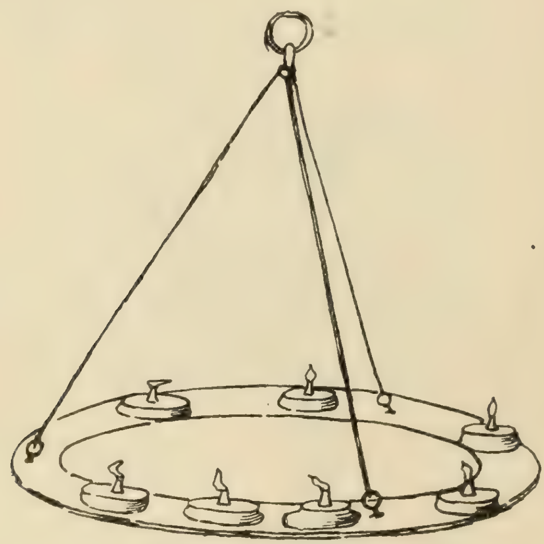


Fig. 13.—Form of Lighting Fixture Used in Early Christian Basilicas.

candle itself. Four of these magnificent fixtures served to furnish the general illumination of the main hall in some old patrician's residence. The effect must have been well-nigh perfect. Indeed, the use of the hanging lamp or oil bowl standard is an inseparable feature of the classic orders, and we find some very fine examples of their use in modern times—note the standards in front of Columbia Library and how, at night, they bring out the noble masses of the building; also the use of the hanging lamps in the foyer of the Manhattan Hotel (New York), where a chandelier, no matter how cleverly designed, would have done much to mar the effect. Chandeliers are, in fact, only possible in certain forms of the Renaissance and modern styles. (See Figs. 5, 7 and 8.) A good example of the use of chandeliers in German feeling is

to be found in the bar and men's café of the Hotel Plaza (New York). Fig. 13 shows the general form of the lighting fixture used in many of the early Christian basilicas. Fig. 14 shows the same fixture adapted to modern methods and used with excellent effect.

(47) The lighting of churches is, perhaps, the most difficult problem of illumination. In Norman and early Gothic churches no artificial illumination was provided. The churches were rarely used at night, and when used, candles at the altar and in the hands

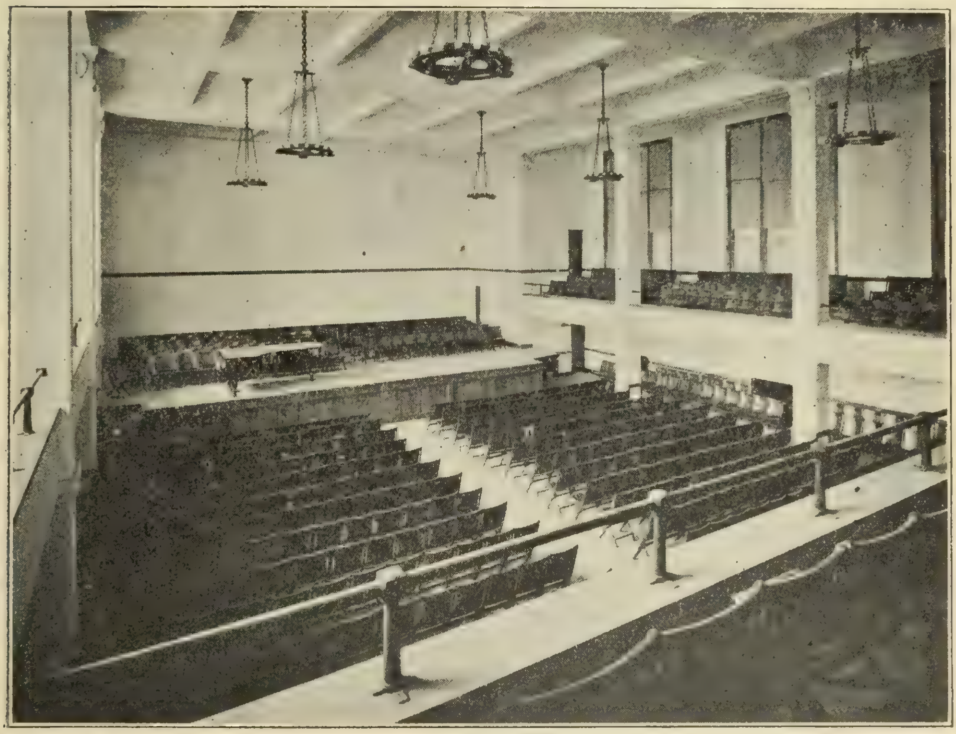


FIG. 14.—ADAPTATION OF FIXTURE SHOWN IN FIG. 13 TO MODERN METHODS.

of the candle bearers of the choir furnished all the light considered necessary. There were no hymnals or prayer books in those dark days, except in the possession of the educated priests and monks, but the religious spirit so permeated the life of even the meanest individual that reading in church was not only unheard of but unnecessary. All of the lighting fixtures now used in historic English churches have been added during recent times, and, with the possible exception of the recent installation in St. Paul's, they are generally inappropriate. In the later French and German cathedrals and cathedrals of French influence alone was

any attempt made to study the requirements of artificial lighting, and to them we must turn for suggestions.

(48) In some early cases a huge corona or crown of candles was suspended from the apex of the vaulting over the interception of nave and transept. No illumination was furnished in the nave, and the resulting effect of the brilliantly lighted chancel and altar with the dimly-lighted arches overhead must have been very impressive. In later times sconces were placed on the nave columns, or sockets were used, into which fitted wrought-iron brackets. (See Fig. 15.) In the designs of the Renaissance period more light was required in the nave, and smaller crowns, chandeliers, or lanterns were suspended from brackets at the spring of the vaulting arches. Additional fixtures, brackets, standards, and

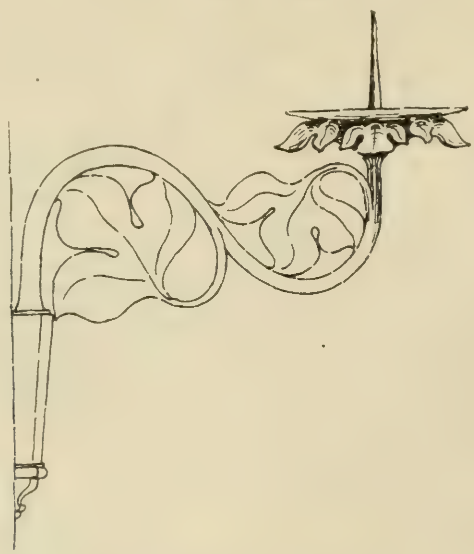
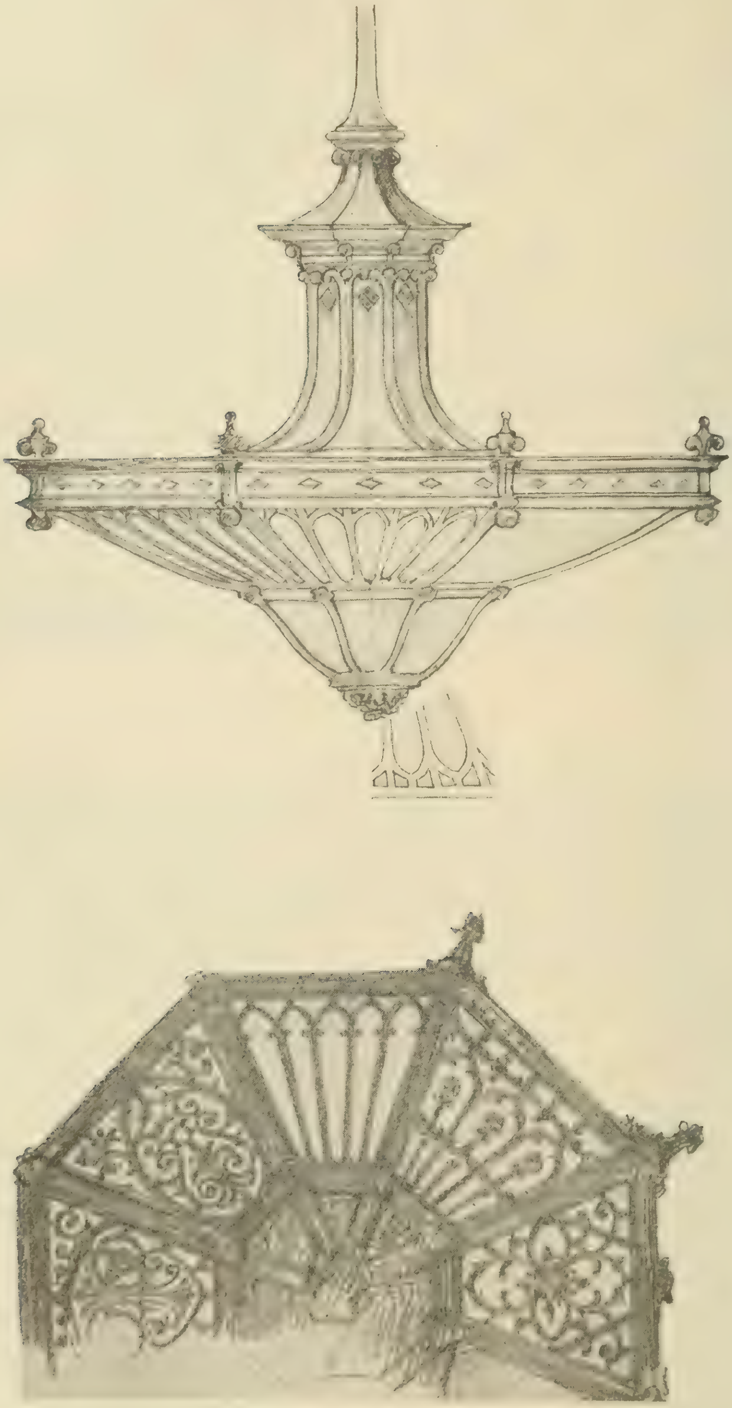


Fig. 15.—A Gothic Bracket.

chandeliers were added at the altar screen and in the choir to maintain the contrast between the brilliantly illuminated chancel and the rest of the church. The effort was always to keep the lighting of the nave comparatively low, and to place the nave fixtures on or near the columns, so that the proportions of the church would be properly accented. The mistake was sometimes made of suspending fixtures from points that were not features in the construction, as from the groin of the vaulting or from the curve of the arches. To avoid this, some ornament or wreath was occasionally added to the neck of the nave columns, or some modification was made in the spandrils of the nave arches, and brackets were sprung from these points to which the fixtures were

Fig. 16.—Use of Wreath Device with Grotesques Worked Into Capitals.

Fig. 17.– Example of the Use of Fixtures as a Part of the Room Furnishing.



FIGS. 18, 18A.—ADAPTATION OF THE ARC LAMP AND INVERTED DIFFUSER TO CHURCH LIGHTING. THE TRACERY OPENINGS MAY BE FILLED WITH YELLOW GLASS.

attached. Fig. 16 represents an interesting use of the wreath device in connection with grotesques worked into the capitals. The quality of the lighting was always subdued in tone and color. Everything in the nature of brilliancy was avoided excepting the glare of the diffused golden light in the chancel.

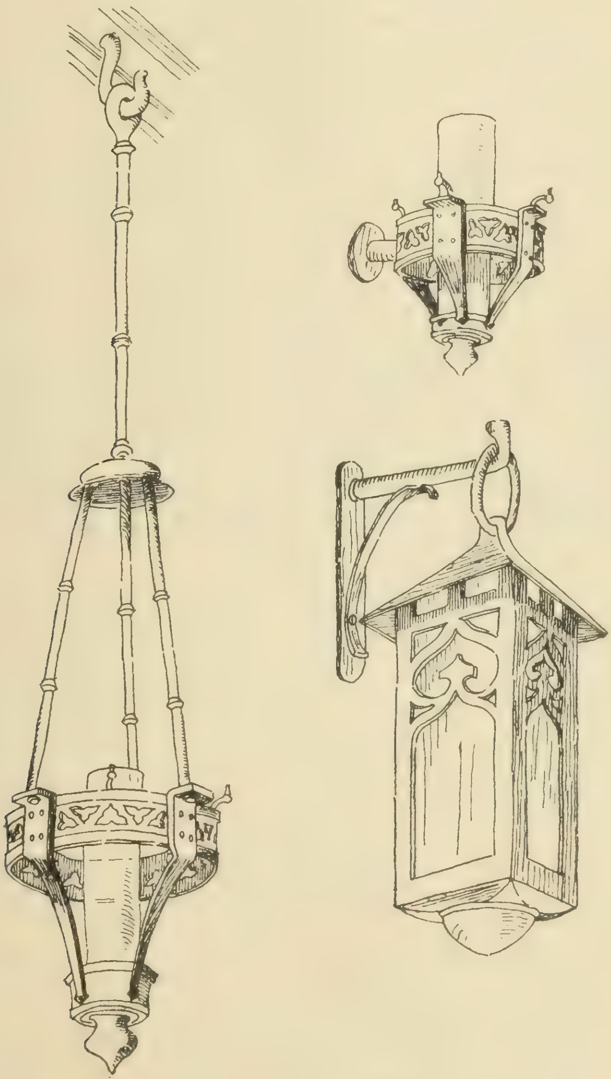


FIG. 19.—FIXTURES FOR A SMALL CHURCH.

(49) The use of glass was, of course, unknown in early work, of mica or skin shields formed the only means of concealing the brilliant flame. In many cases intricate tracery work in the lanter faces was used to subdue the quality of the light. (As a modern example, see Figs. 18 and 18a.) The diffusion obtained

by this means was usually better than we might expect. It is, at any rate, much more suitable and pleasing than any effects that are obtained by modern prismatic glass and scientifically designed reflectors.

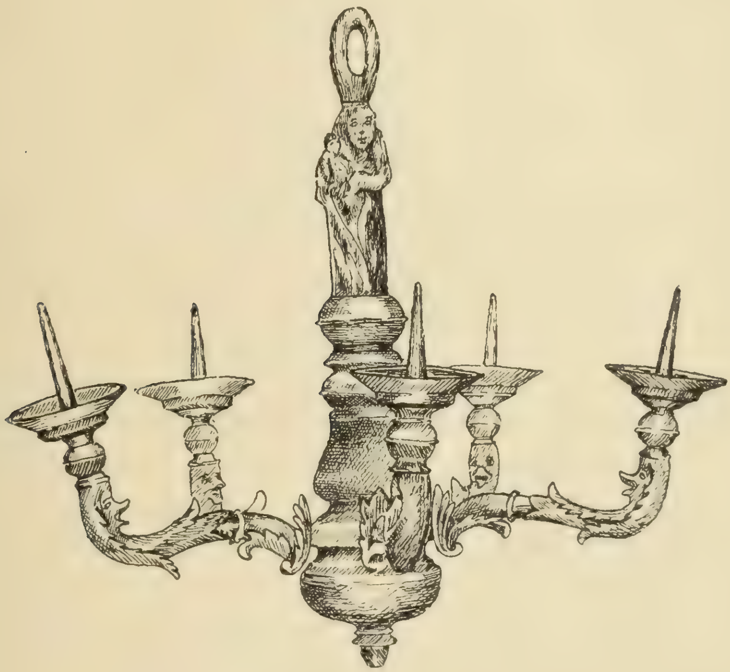
(50) A study of the history of church lighting will make one fact evident. The palpable artificiality of every kind of illumination presents an almost insurmountable difficulty. It is practically impossible to design any adequate system that would not seem totally out of place in such interiors as that of Durham and Amiens and the earlier portions of Canterbury or Westminster Cathedrals. The architecture of these great edifices makes its appeal purely through the sublimity of its proportions. Decoration and ornament are unnecessary and have been but sparingly used. To attempt to light these buildings by any means less impressive in its effect than they are themselves would be little short of desecration, and artificial illumination is essentially decorative in its results. It may, in general, be taken as a rule that the simpler the architecture—provided it be good architecture—the more difficult becomes the problem of illumination.

(51) Is it only by such historical study that we can learn the nature of the ideal which the great masters of architecture sought to embody in their work, and only as we succeed in making this ideal our own, can we hope to express, in our efforts, the truth of architectural beauty.

PHYSIOLOGICAL.

(52) This paper has carefully avoided any discussion of the physiological effects of artificial illumination, for it is the writer's belief that no architectural design, conceived in the right spirit, and properly executed, can demand any suitable artificial illumination that is injurious in the optical sense. The reasons for this lie deeper than the physiology of the eye can lead us, and have to do also with visual perception and psychology. It is a subject demanding separate treatment and cannot be encroached upon in this discussion. Artistic illumination is, *ipso facto,* good illumination. And no illumination can be artistic that is not conceived as a feature of a truly artistic design.

The author has to express his thanks to Messrs Palmer and Hornbostel, Mr. B. G. Goodhue, Messrs. Bosworth and Holden, and the Enos Co. for illustrations, and to Mr. H. E. Watkins, and his brother, Mr. S. W. Jones, for advice, criticism, and suggestions.



OLD CHANDELIER.

DISCUSSION ON JONES, "THE RELATION OF ARCHITECTURAL PRINCIPLES TO ILLUMINATING ENGINEERING PRACTICE," BY THE NEW YORK SECTION.

The Chairman (E. L. Elliott).—We have listened to probably the most important paper that has been presented before the New York Section of the Society. I say this from a firm sense of conviction and belief, and not from any mere wish to pass a routine compliment. We cannot deny the fact, no matter what importance we may attach to mathematical engineering, that no system of illumination can be called a success that is ugly or offensive to the aesthetic taste.

There is an old saying that questions of taste—and the paper presented this evening has dealt largely with this subject—do not

admit of discussion; but like many old sayings, it has to be taken with "a grain of salt." It seems to me that questions of taste are about the only subjects that are debatable; questions of fact assuredly are not.

L. B. Marks.—This paper treats of a subject which has been given scant attention in the *Transactions* of the Society, and contains much matter of very great interest to illuminating engineers.

I hardly agree with Mr. Jones that the illuminating engineer who considers only the scientifically practical side of the profession is necessarily doomed to ultimate failure. There is a large field for the illuminating engineer where aesthetics is only of secondary importance; in this field the illuminating engineer may achieve success even though he does not concern himself personally with the purely artistic side of the work.

In viewing broadly the purpose of architecture, Mr. Jones says the mind asks instinctively when contemplating a structure, "What is the thing for?" I ask the same question with regard to lighting fixtures. If they are intended primarily to enable us to see, then "no amount of grace or ornament can overcome the ensuing feeling of repulsion" if they fail to do so!

The English wall bracket shown in Fig. 1, would not to my mind serve its purpose properly as a lighting fixture no matter how exquisite the harmony of its curves may be, unless the intrinsic brightness of the lamps provided therein falls below a certain limit. At the present time the use of wall brackets for the illumination of fine residences is perhaps more in vogue than at any time since the introduction of electric light. These brackets are often provided with small round lamps similar to those shown in Fig. 1, the lamps often being sixteen candle-power. The result is that not only is the effect of the beautiful lines of the fixture lost to the eye, but the glare of the lamps is most prejudicial to the eyesight. In a fixture that is intended to give useful light rather than decorative effects, I hold that the importance of engineering in the design takes precedence over aesthetics; if the design be for decorative illumination only, I should reverse this order, still bearing in mind that engineering may play an important part in securing the decorative effect desired, in the most economical and scientific way. Thus, in Fig. 2 for instance, the use of the ornament at the bottom, to bridge the discontinuity in lines of the fixture, may be clever from

an artistic point, but not so clever from an illuminating standpoint.

Mr. Jones states that "The business of the illuminating engineer is to modernize old methods of illumination without destroying them." This holds true where it is desirable to maintain tradition. Generally speaking, I hold that it is the business of the illuminating engineer to modernize old methods and to discard them where new and better ones are available.

Referring to Figs. 7 and 8, Mr. Jones says, "No other scheme of illumination and no other style or type of fixture could have been used without marring the entire effect. Such illumination is good illumination."

Waiving the question of aesthetics, I take issue with Mr. Jones that such illumination is necessarily good illumination. Though the lighting fixtures in the Grand Trianon may be and undoubtedly are exactly suitable from an artistic standpoint for the rooms referred to, they leave much to be desired as producers of useful illumination. For instance, referring to Fig. 8, in viewing some of the pictures at close range the observer would necessarily be between the light and the picture; while at longer range the light would strike his eye at a harmful angle.

Mr. Jones says that it is not a question of foot-candles, that it is a question of how much light is needed, and that it is more often a question of quality rather than quantity. It seems to me that all these questions come within the legitimate field of work of the illuminating engineer. While the architect in endeavoring to secure the particular effect which he desires may adhere to empirical methods, the illuminating engineer is or should be enabled to secure the effect by exact and scientific methods. I hold that it is a question of foot-candles. But in planning to secure a definite number of foot-candles the engineer must take into consideration the question of quality of light as well as intrinsic brightness, and a number of other factors.

Mr. Jones calls attention to the fact that good lighting has been achieved in the past by empirical methods and that we are simply in a position to do more efficiently what the masters have done in spite of their manifest limitations. I hold that illuminating engineering is gradually giving us definite and accurate methods of producing good results which heretofore have only occasionally been brought about by empirical methods.

The statement is made that "it is in fact impossible properly to light a design that has not been conceived as illuminated and suitably adapted therefor."

This seems rather a broad statement, but if it be true it is all the more important that the architect, unless he is an expert in illumination, fortify himself with the best available illuminating engineering talent. Co-operation between the architect and the illuminating engineer, at the inception of the building design would result in providing for a suitable illuminating design for which proper provision cannot in many cases be made, once the plans have advanced beyond a certain stage.

The architect gives a great deal of thought to the question of day-light illumination, which question usually, if not always, plays a very important part in his conception of the design of a building. But does he give the same attention to the question of artificial illumination? My experience has been that he rarely considers the latter until after his building plans are complete, and then usually considers it from its aesthetic and not its engineering side. It seems to me to go without saying that barring cases of exact reproduction of historic fixtures, as for example in a Louis XIV room, the architect must needs concern himself with the engineering side of illumination if we are to make real progress in the design of interior illumination. The position of the architect is very different now than it was a generation or so ago. Then he had comparatively few illuminants with which to deal, and was restricted to narrow limits in the choice of their location. To-day he has many illuminants to consider, and is practically unrestricted in their location in many cases, and has at his command new means for directing and distributing the light.

Mr. Jones presents an illustration, Fig. 14, showing the adaptation of an ancient lighting fixture shown in Fig. 13, to modern methods. He says that the effect is excellent. From an artistic standpoint this may be true, but from an illuminating standpoint the effect may be very bad if the lamps which are used in the fixture have a high intrinsic brilliancy. These lamps are exposed to view and most of them are within the ordinary field of vision of persons seated in the balcony shown in the illustration.

In connection with the lighting of churches, while it may be true, as Mr. Jones says, that any attempt to light these buildings by any means less impressive in its effect than they are them-

selves, would be little short of desecration, the fact remains that the artificial illumination provided in the old churches (see illustrations Figs. 3 and 5) is totally inadequate, and from an illuminating standpoint wholly unsuited to present day needs. The problem of church illumination is extremely difficult in any case and particularly if ancient traditions are to be conserved. Here again is a case in which the need of applying good illuminating engineering to architectural principles is manifest.

Mr. Jones, I think, in a sense, begs the question when he says, "Artistic illumination is *ipso facto* good illumination." Good illumination in its broad sense must conform not only with the canons of art but also with those of science. In a narrower sense, the science of good illumination, including, as it does, the consideration of the hygienic or physiological as well as the economical, comprehends factors that need not necessarily enter into the realm of the artistic. In other words, from this point of view illumination may be artistic but still very bad.

In closing, I wish to thank Mr. Jones for the valuable facts, ideas and suggestions he has put before us, and to say that though I do not agree with him in some of the views expressed, I have derived much benefit from reading his paper.

Mr. Clark.—I agree with much that is contained in the paper. I think one of the most important buildings put up recently is the New York Custom House. The architecture, I believe, has been thoroughly commented upon, and very few words said about illumination. I think if those who live in New York will go down there and examine that building it will be a good illustration of the principles contained in the paper which has been presented to us this evening.

S. W. Jones.—According to Mr. Jones and his paper, it would appear that most illuminating engineers will have to go back to their youth and be re-educated, go back to school and be brought up under conditions which would develop in them an aesthetic sense. This is impossible, as we have to deal at the present time with present problems. The illuminating problems of the present day may, I think, be aptly divided into two classes, modern buildings, such as office buildings, loft buildings, and buildings for mercantile purposes, and then those which are created on historic principles. The former, I care nothing about dealing with, because those we can leave, I think, safely in the

hands of the illuminating engineer to be handled from an engineering standpoint; it is simply a question of efficient lighting. As to the latter, as an architect, I feel very strongly inclined to state that the architect is best fitted to cope with the problem of illuminating such buildings. As Mr. Jones has stated in his paper, the illumination must be conceived with the design. That, I think, is the common practice with good architects. Of course, there are a number of architects who pass lightly over the subject of illumination and, to the extent that they do this, they blunder. We find a great many results which are far from pleasing, owing to that fact. I have recently had one experience, which I think might be well stated here, where the illuminating engineer for a certain building—in fact there is a picture of it in the paper—I think it is Fig. 17, where it shows an example of the use of fixtures as a part of the room furnishing. These fixtures, as shown, have seventy-two lamps each. The illuminating engineers' plans, or the electrical engineers' plans, provided only for thirty-two lamps. Thirty-two lamps, from the engineers' standpoint, were sufficient to light the room, with the other lamps provided, but when it came to the point of designing the fixture, the fixture required was so enormous, that thirty-two lamps would have been absolutely inefficient. It became a question primarily of a suitable fixture, and since the fixture would be unsuitable for thirty-two lamps, the additional lamps were therefore placed upon it. The lamps were adapted to the fixture, rather than the fixture to the lamps.

As to the further important argument, that the architect shall dictate in the matter of illuminating buildings based on historic creation or principle, it seems to me that it narrows itself down to the point of a comparison of the education of the architect and of the engineer. The engineer, by reason of his education, is unsuited absolutely for the work which he sets out to do, in this particular class of building. He has no conception of the effects desired. He has no creative ability, no knowledge of the history of architecture and history of ornamentation, and, in fact, he is working in the dark absolutely. I think I am backed up by the profession largely, in stating that the architect feels that he should dictate in such matters, and that the engineer should follow his dictates, and that this will produce the most efficient results along the lines laid down by the architect. As Mr. Jones has

stated—and I think correctly from the architect's standpoint—suitable illumination is good illumination, and no matter whether the illumination is efficient from the engineer's standpoint or not, if it is offensive it is not good illumination from the architect's standpoint or the standpoint of the public.

W. S. Kellogg.—Mr. Jones, in paragraph 21, says "The merchant contemplating the success of his scheme, the scientist contemplating the success of his investigation, the artist contemplating his creations: in all we find expressed the sense of beauty." In the olden times the savage put up a shack to keep out the elements, but it was not architecture. As we progress we learn that the desire for beauty is primarily the cause of architecture, hence any purely mechanical appliance that disregards this principal is unsuited to be a part of an architectural composition.

In paragraph 27 Mr. Jones says: "A lighting fixture must be proportionately heavy if it is to be employed in a room of massive construction, otherwise the feeling of balance will be disturbed." This is known among architects as "scale," i. e. the parts must be proportioned one to the other while conveying a proper sense of size. One of the most conspicuous examples of perfect proportion that yet is entirely lacking in scale is the church of St. Peter's in Rome. This may seem to be a strange statement until it is explained that in order to appreciate the vastness of anything there must be some object present so familiar as to suggest at once a direct comparison, such as a human figure, life size. In St. Peter's this familiar object has been used to deceive the eye instead of assist, for near the entrance is a holy water well supported by two little cupids that are larger than the largest man instead of the usual size of a child, as a consequence no one is impressed with the size of the building, and many visit it without thinking that it is the largest of Christian churches. In designing fixtures as well as buildings it is manifestly necessary to keep them in harmony with the setting. If incandescent lamps be used to light a large room, sufficient light can be obtained if the lamps are suspended from cords, but if any attention has been given to rendering the room attractive such an arrangement can never be described as satisfactory no matter how efficient from a utilitarian point of view.

In paragraph 31, Mr. Jones says: "Ornament not to be vulgar must be handled with exquisite taste and sense of propriety, for

in ornament more than in anything else we may read the mental standards of the period. An intimate knowledge of its history and use is essential for its proper treatment." In view of the commercial methods in vogue to-day, that paragraph means much. Stock fixtures, lamps and electrical appliances are turned out at a very low cost, but sad to say, they attempt to satisfy a vulgar taste by adding so-called ornament with no addition to the cost of the objects and, as might be expected, the stamped ornament so much used is too fearful to describe. Better make all stock material severely plain, as good simple lines and surfaces are in better taste than any cheap ornament.

In paragraph 33 we find "I have noticed on the part of many contributers to the literature of illumination, a disposition to decry and criticise the limitations which architects place on their work." This charge is made by all who come in contact with the architect. If the architect allowed each contractor to do as he pleased the resulting structure might be interesting as a museum of the arts, but the owner would be apt to find it quite unsuited to his purpose. The architect must be an arbitrary person, or all of his time would be spent in polite explanation.

In paragraph 33 Mr. Jones also remarks that "The business of the illuminating engineers is to modernize old methods without destroying them. That is quite true. In the old days they used a dish of oil with a wick floating in it, but the ancients would have been glad to exchange the smoke and smell for some of our improvements. It is questionable, however, if they would not have been content with the mechanical improvement and been as well satisfied with the old quantity of light. The present tendency is not increased efficiency of the old units to which we are accustomed, but rather a move toward lamps that give increased light for the old consumption of current. In the old days people found candle light very satisfactory, but expensive, and as they now can use gas, or oil, or electricity at less cost, they are generally used, and the candle is used on the rare occasions when its portability or softness of light makes it far preferable. The present sixteen-candle-power unit, as used in incandescent lamps is, in my judgment, too high; my preference is for a standard lamp of eight-candle-power or smaller. The present prevailing habit of wearing glasses is due very largely to our abuse of modern improvements in the lighting units. I came to appreciate

this a short time ago when investigating some complaints of poor lighting in a building recently built, in which I gave particular attention to getting plenty of light. When the complaints started I laughed at them, but as they continued I made up my mind to visit the building. Some of the attractive glass advertised to cure all lighting troubles had been used and the result was a glare of light coming from all directions that made one's eyes ache. There was twice the light that was necessary, but as the users knew it hurt their eyes they complained of lack of light, while the remedy was, reduce the intrinsic brilliancy.

In paragraph 34, Mr. Jones says: "Note the absolute harmony both in proportion and in detail, denoting throughout the expression of a single idea. No other scheme of illumination and no other type of fixture could have been used without marring the entire effect. Such illumination is good illumination." The room described was not intended to be lighted to permit the easy reading of the daily paper. The modern millionaire who desires a reproduction of this room in his home and insists upon the brilliant lighting of a bar room should blame the lighting layout, not the long suffering architect, when the room is found to be quite different in effect from the original.

Mr. Jones further says, in paragraph 34: "The laws of construction are an after consideration, a means of checking the proportion, to see if it is safe. So, too, the illuminating engineer must use the laws of distribution, not as a method of determining what the distribution shall be, but as a means of adapting the lamps to the distribution required. It is not a question of foot-candles, it is a question of how much light is needed. And it is more often a question of quality than quantity." This is the keynote of successful illumination. He who is primarily interested in the quality of the illumination must, as a result, secure just the right amount of light, as otherwise the quality will not be all that is desired. The great curse of the engineering profession is the inbred belief that efficiency is the only thing that counts. Some years ago I met an engineer who has just visited the great monuments of Rome. He was not pleased with them. He said the Romans were not engineers, because any fool could make a structure stand if he used such an excess of material. He probably thinks a steel railroad bridge more beautiful than an old

Roman aqueduct, but some of us are glad to stand without his gates and keep to our childish beliefs.

V. R. Lansingh.—After hearing what some of the gentlemen have said here to-night, it seems to me taken for granted that the illuminating engineer cannot possibly have any sense of the artistic, and on the other hand that the architect cannot have any sense of engineering principles; that each is engaged in his own line and cannot understand either the motives or the feelings which prompt the other; this view, I am sure, should be modified. It is true that a large percentage of the work of the illuminating engineer is purely utilitarian; dealing, as it does, with the lighting of office buildings, warerooms, stores, etc., where the artistic effects are not necessarily of primary importance, but it seems to me that if the illuminating engineer is of the high mark which we would all wish to have him, he should be thoroughly in sympathy with the ideas which move the architect. On the other hand, the architect should certainly know the fundamentals of illuminating engineering just as he is required to know the fundamentals of other engineering branches, and he should be able to carry out his artistic ideas with an eye to both economy of cost and operation.

In those places where the fixtures and the lighting must, on the whole, correspond with the architectural features of the building, I am thoroughly in sympathy with the ideas of Mr. Jones and Mr. Kellogg; that the architectural treatment of the subject must be considered first, and that the artistic requirements are of primary importance. Nevertheless, it is possible that even in such a case the skill of the illuminating engineer can be used to good advantage without sacrificing the architect's ideas.

The lighting of the lobby of the Manhattan Hotel has been spoken of several times. I believe that in this case economy is of practically no importance, inasmuch as the artistic requirements are to be considered first, and any attempt to cut down either the first cost or the operating cost would have been ill-advised. Such examples as this, however, are few and far between, and even in such cases the skill of the illuminating engineer can, as a rule, be used to produce the same artistic effects at a lower cost.

In Europe I believe that ten-candle-power, rather than the sixteen-candle-power lamp, is standard, and I look forward to a great development in our lighting when we can make the newer

types of metal filament lamps in smaller units. This is especially true of residence lighting.

The example of the Grand Trianon has been mentioned several times to-night. It is true that the lighting of this room, considered as a ball room only, is good, but when used for its present purpose, as a picture gallery, the lighting is probably poor. The lighting of a room should be in keeping with the purposes for which it is designed, and we should certainly not blame the lighting if it is not in keeping with the changed uses. In such a case as this we would have to choose between lighting our pictures and sacrificing to some extent, the idea of the room as a whole, or on the other hand, to sacrifice the lighting of our pictures.

A. J. Marshall.—I have listened to Mr. Jones's paper with a great deal of interest, but I desire to take exception to his statement that the illuminating engineer has, unfortunately, little opportunity of learning to appreciate beautiful things, and that his limitation in this regard often leads him to accent what he terms practical considerations.

I think it is a grave error to suggest that there are no illuminating engineers capable of dealing intelligently with the aesthetic, as well as the economical and practical sides of illuminating engineering. Men who are interested, and vitally interested in this movement, have worked hard and earnestly to bring this science to the public in such a way that they would consider it of importance to have someone who was familiar with the different phases entering into the work, to take charge of it.

If Mr. Jones desires simply to make the statement that illuminating engineers should know the aesthetic side, I most heartily agree with him, but if he makes the statement that there are no illuminating engineers who appreciate and are capable of handling this phase intelligently, then I most assuredly disagree with him. There are some illuminating engineers who are thoroughly qualified to discuss things architectural with some of our best architects, but of course, engineers of this ability are not running around loose, willing to give their opinion on some intricate installation on the spur of the moment.

As an example of an architect's conception of what should be used under given conditions, I refer to the lighting system employed in the cafe of the new Plaza Hotel, New York city. Ref-

erence, to-night, has been made to this lighting system as being, as a whole, harmonious and attractive. If my memory serves me right, the lighting fixture used in this cafe contains candles, which in turn are equipped with round, frosted lamps to imitate a candle flame. Personally, I have never had the pleasure of seeing any symmetrically, round candle-flames, but as these are spoken of as German fixtures, it may be that such candle-flames can be found in Germany.

George H. Stickney.—The paper deals in a masterly way with a line of thought which it is difficult to express. The extreme idealistic treatment is no doubt intended to counteract the tendencies to which engineers are liable. In reality those who have had the greatest amount of experience in illuminating engineering, have realized the importance of the aesthetic considerations in certain classes of lighting problems. They have given this phase of the problem much more thought than is commonly supposed.

Naturally the illuminating engineer was first called in on those problems where economy and effective distribution of light were of maximum importance, and the aesthetic quantities secondary considerations, as in the case of ordinary workrooms.

Going from such problems to those of store lighting the increased importance of the aesthetic considerations becomes immediately apparent. At the other extreme we find fine churches, public buildings, hotels, and the like, where emphasis is placed on the architectural features and decoration. Here economy must give precedence to the aesthetic.

The experienced engineer approaches such a problem with considerable caution, and if possible works in co-operation with the architect responsible for the design.

The paper appears to criticise the methods of the architect as well as those of the engineer. The highest success of either vocation must certainly depend on intelligent co-operation of the architect with the illuminating engineer. Some of the best architects realize this and are relying more and more on the recommendations of the illuminating engineer.

On the other hand, it is incumbent on the illuminating engineer that he weigh his problems with care and give proper value to aesthetic considerations as well as engineering questions. It is also very important that illuminating engineers should be accurate and true in the determination and use of data. No greater

danger threatens illuminating engineering as a profession than the discredit which will be sure to follow a careless and unscrupulous handling of data.

In lighting problems a peculiar condition exists due to the close and frequent comparisons which can be and are made between the artificial illumination and daylight. Whether the illumination be intended to supplement daylight during the hours of darkness or to extend illumination to places where daylight is inaccessible, the users have frequent opportunities for comparison. The comparison is usually to the disadvantage of the artificial illumination.

The sun sets us a standard which demands improvement in artificial illumination as fast as our knowledge of materials and methods permits. In responding to the demand the engineer sometimes tends to neglect historical standards.

I wish to speak a word for the fixtures which have been produced by manufacturers of the various forms of illuminants. In general, these have appeared to satisfy a demand for greater consideration of the economic element. Some of these fixtures have undoubtedly violated some of the usual requirements of aesthetic design. In some cases this has been due to lack of knowledge on the part of the designer, but a large degree it was due to the economic limitations.

In some particular cases, I know that the engineers have felt this lack, and have made every effort to conform with æsthetic requirements as much as possible without seriously detracting from the practical value of their apparatus.

Mr. Hopkins.—The fixture designer and the manufacturer of lighting fixtures have been interested observers of what has been developed by the illuminating engineers; they have kept themselves posted on the new appliances that have been produced from time and have read the criticisms made against some of their cherished traditions in regard to fixture construction. We are delighed that an article has at last appeared in which our opinions on the important question of proper artistic illumination are so ably and fully stated. So admirable a paper as we have listened to needs no additional arguments and what little I may say will be merely to lay particular emphasis on some if, what we consider to be, the most important points.

As far as I know the term illuminating engineer is only about six years old and the profession of illuminating engineering is

a product of our own day. It seems to have grown up coincident with the development of high candle power, electric lamps and prismatic glassware. Viewed in its broadest sense it would seem that the term "illuminating engineer" is not entirely suited to the profession, but that "lighting expert" or "lighting specialist" would more fittingly describe the broad scope that the profession should cover. One of the oldest theories regarding an engineer is that his function is to produce ultimately the most interest for every dollar of invested capital. This I admit is a sweeping definition and might be applied equally well to other professions than that of engineering. Engineers in other branches supply the architect with his working data regarding the strength of steel, iron, concrete and other material. They calculate the strains in supporting members, aid him in the selection of the building materials and provide for the purely mechanical portion of the equipment. As the author has said, "This data furnished by the engineers is a means of checking the proportion of construction that the architect plans to adopt." So the illuminating engineer should determine the power and efficiency of certain light sources, plot the curves of intensity if required and arrange for the purely machanical means of locating and distributing the light of the quality and quantity desired by the architect in completing his design. In doing this, "he must modernize old methods of illumination without destroying them." The illuminating engineer can exercise the function of engineer to excellent advantage in office buildings, stores and other structures that are commercial in their character and are relatively bare of ornament. In such cases the lighting fixtures may properly be considered to be a portion of the engineering equipment of the building and, therefore, subject to the same study and planning for efficiency and economy. Equipped with his data regarding light curves, efficiency and candle power of the latest type of lamps, and values of wall and ceiling reflection, he can safely be trusted to recommend appliances for such cases and show a true economy of maintenance. In this instance lighting comes under the same heading as heating, ventilating, elevator service, etc.; and the cost of suitable light per square foot of rentable office or floor area is the item that vitally concerns him. Where for scientific reasons he thinks it is necessary, the fixture designs must be in accord with his plans. It would appear that this

might be a narrowing field to the ambitious engineer. By his work he is training others and the problems being repeatedly solved in a simple way cease to be problems where conditions, as is often the case, are very much alike. It might of course be argued that lighting appliances are being continually improved, that new lamps and reflectors are being produced and that this in itself gives novelty to the solutions of the problems, but the illuminating engineer, be he satisfied only to keep posted on such matters, is not training himself for his broadest usefulness. He is content to be an engineer and not an expert, if I may be permitted to draw this distinction. The danger arises when in his zeal for economy of maintenance the illuminating engineer attacks the more difficult problems where the architect has designed with a definite purpose and where he attempts to apply the same rules and follow the same method of procedure as he has in commercial buildings. He becomes dangerous to the extent that he fails to consider just the limitations imposed upon him by the architect's design.

I cannot help thinking that in the matter of lighting there seems to be too sharp a line drawn between cost of maintenance and interest on investment. Can we suppose that an intelligent building owner is willing to expend thousands of dollars on the ornamentation and decoration of his building, on the rugs, paintings and other furnishings which he and his architect have selected with the most pains-taking care, so to warp his judgment as to jeopardize the returns in satisfaction and pleasure from the investment represented by the cost of these decorations and furnishings? Take, for example, the magnificent new Plaza Hotel (New York), just completed. I suppose the decorations and furnishings of this hotel represents an outlay running into the hundreds of thousands, if not millions, of dollars, and this investment represents an annual cost of thousands of dollars as interest on the invested capital. Would it not be the height of folly to allow the consideration of economical lighting to be carried to such an extent as to minimize ever so slightly the beauty and attractiveness of the equipment represented by enormous investment? It would be far better if the error should be on the side of a trifle too high a cost of maintenance, if the most appropriate illumination from the architectural standpoint could thereby be secured.

There seems to be a feeling that the fixture designer and lighting specialist has been working in the past on a purely hit or miss principle; that he has not possessed the necessary scientific data to handle the subject properly, and that he has not given it the careful study that he should. While this may be true of some so called designers of fixtures, it is by no means true of all, we are glad to say. We admit that there are many examples of badly constructed fixtures on the market and will continue to be so long as there are manufacturers who are either uneducated or unscrupulous as regards the proper methods of construction. The standard of some manufacturers seems to be a standard of quantity of brass work, regardless of the appropriateness of the fixtures that they recommend for the locations where they are to be used. In some cases the customers themselves are to blame for such poor designs, as they are entirely misinformed as to what they require and insist on having faulty constructions against the advice of the fixture designer. It is only fair to say that the latter are loath to furnish such constructions and often put forth all their efforts to persuade the costumer to have what is right, even to the extent of destroying some of customer's pet schemes of lighting. It occasionally happens that a designer will go to the extent of declining an order rather than furnish fixtures that he knows are ill suited to the customer's conditions.

It is difficult to tell just where the fixture designer and lighting specialist should begin his work. In important cases it might be advisable to have the fixtures considered before the complete plans are drawn, and certainly before the electric outlets are located definitely. Many and many a time, in studying over the plans for some installation, he has found that the outlets are poorly located for a distribution of light in accordance with the architectural scheme, making it necessary for the customer to change them, even at a considerable expense. It is only fair to say that in such cases the customer has appreciated that this apparently unnecessary outlay was entirely warranted.

Remember that the fixture designer and lighting specialist has studied ornament and decoration for years. He is thoroughly conversant with its historical precedent and knows with that deep-rooted knowledge that comes with observation and study, the proper treatment that it should be given as regards illumina-

tion. Is he open to criticism because he does not talk glibly of foot-candles or seize upon every new lamp as soon as it comes out? Do not think that he does not make intelligent use of these methods of calculation nor does not weigh the value of any new appliance; he uses them intelligently, just as far as the limitations of the design will permit him to. The fixture designer has been trained in the school of experience and each difficult architectural problem that he successfully solves gives him the necessary data to aid him in the solution of problems of a similar nature. These similarities do not arise very often and, as a whole, each plan must be treated as a distinct problem, but there are certain fundamental principles that he has worked out successfully on other installations that can be modified to meet the problem under consideration. It must be born in mind that problems in illumination do not admit of exact solutions. The sources of light vary in intensity, the various reflectors lose a portion of their value if not properly taken care of, and there is always considerable uncertainty regarding the value of the reflection from the walls and ceilings.

As regards the light required for different conditions, there also seems to be a large field for the exercise of judgment. There has been a table prepared giving the number of foot-candles required, or recommended, for different conditions, and I found that they vary with a range in some cases of 200 per cent. In view of this it would seem that while the illuminating engineer can make use of certain figures and information that he secures from tests of different appliances, he must largely exercise his judgment, and this judgment must be backed by the experience obtained by successful accomplishment. In other words, both the fixture designer and the illuminating engineer base their work on data and information that is the result of actual experience. Is it not much more important, then, that the fixture designer and lighting specialist shall make a careful study of the lighting problem in the light of its architectural value, rather than in scientifically calculating just what number of foot-candles this light may reasonably be expected to produce and comparing his result with some arbitrary table of figures?

Reference has been made in this paper to the lighting of the corridor of the Manhattan Hotel, and can it be supposed that this lighting was done on the hit or miss principle?

This corridor is one of the most beautifully lighted rooms in the city, and it is interesting to note that the fixtures furnishing this light violate many of the structural rules formulated by the illuminating engineers. The lamps are directed upward in a vertical position and they have a considerable mass of metal directly beneath them. On the other hand, the fixtures are in absolute architectural harmony with the surroundings, and careful consideration was given to the matter of diffusion of the light by the use of opalescent glassware and also from reflection from the light tinted ceiling and walls. After inspecting such an installation, can we feel for one moment that this is the result of guess work?

Reference has also been made to cafe of the new Hotel Plaza, and it might be interesting to ascertain what the illuminating engineers would have recommended for these particular locations. It might be that they would have recommended fewer and more powerful lamps; they might have suggested prismatic reflectors, to throw the light to the floor; or, perhaps, they might have taken away the fixtures altogether and suggesed some form of concealed or ceiling lighting. This problem, like all others, was very carefully considered. The designer put himself into absolute architectural harmony with the scheme of the architect, and the result is probably perfect illumination from an architectural standpoint. In all these cases the fixtures are massive and are of much more than the required strength for the mere support of lamps. They are absolutely a part of the architectural decoration of the room, and their absence would make a break in the continuity of the architectural scheme.

J. S. Codman.—For a long time the illuminating engineer has been prodding the architect, and the fixture dealer, and getting no response, and he had begun to think that he was thrashing a dead donkey. At last, however, the architect and fixture dealer have awakened, and hit back hard at the illuminating engineer. I think the illuminating engineer welcomes the attack and is glad to be on the defensive, and on the whole, the defense he has made to-night has been a good one. Generally speaking, he has denied most of the charges. He says, first, "I do not pretend to know it all"; secondly, "I do not believe that the artistic should be entirely subordinated to the utilitarian. On the contrary,

I feel that in a great many cases the artistic side of the question is by far the more important."

The fact is, that since the formation of the Illuminating Engineering Society, the illuminating engineer has been continually urging on the architect and fixture dealer the importance of the hitherto neglected engineering side of the question, and it is, perhaps, natural that the architect and fixture dealer have jumped to the conclusion that he could think of nothing else.

E. L. Elliott.—In the work of their professions, the architect and the illuminating engineer meet on a certain zone of neutral or common ground. That the laws of neutrality may be properly preserved therefore, it is essential that both parties recognize the boundaries of this zone; after which each can range with more or less liberty over the preserves of the other without being looked upon as a "poacher." Let us therefore attempt to discover the boundaries of this common territory.

The word "architect" literally means the "master-builder," and this broadly defines his profession. A building is made up of many elements, the details of which the architect must be more or less familiar with, but it is his special business to see that all the elements are properly co-ordinated, so to as to make the total result a complete and successful unit. The number of elements entering into the structure and design of modern buildings is vastly greater than anything conceived of in ancient or mediaeval times. With this great increase in the elementary problems has come a demand for correspondingly greater knowledge of details, with the result that, in many cases, the requisite knowledge has broadened to such an extent as to render a sub-division necessary in order to leave the master-builder free to follow his legitimate office of co-ordinating the various details. This has given rise to an increasing number of specialists, or engineers; and the latest among these is the illuminating engineer.

Take, for example, the modern sky-scraper. It is almost entirely an aggregate of engineering problems; there is very little "architecture," in the old sense of the term, necessary in its construction. In fact, it is quite conceivable that such a building should be put up by an engineer, with possibly some assistance from an architect acting simply in a consulting capacity. On the other hand, the new public library, and the Cathedral of St. John (New York) are essentially architectural works.

While each has its utilitarian purpose, as structures they stand for much more than a mere store-house for books, or meeting place for worship. Good or bad, they stand as monuments of the building art as conceived in the beginning of the twentieth century.

After all is said and done, however, a building is primarily utilitarian; and by far the largest part of all buildings are essentially utilitarian, and only incidentally architectural. Among the utilities of building none has changed more in its relative importance under ancient and modern conditions than artificial lighting. The greatest monuments of ancient architecture are the Grecian temples, and we have no definite knowledge to-day of how these were lighted, either by artificial or natural light. They had no means of receiving daylight unless through the roofs, which have long since disappeared. As they were temples of worship, it is probable that only dim illumination was desired; and yet these comparatively unlighted heathen temples are taken as models for the construction of every form of modern building, from a garden house to a sky-scraper, regardless of the purpose for which they are to be used, or the location in which they are to be set. A building intended for the observance of religious rights in its interior, and perched on a commanding eminence in the peculiarly brilliant atmosphere and sunlight of the Mediterranean, is revamped for a building to be used as a modern library or office building, and crowded in among the plebian structures in the narrow street of a modern city, whose atmosphere is thick with soot from rolling mills and foundries. Such is the power of "historic feeling."

The modern building is, generally speaking, the joint work of engineer and architect; to the extent that the purpose of a building is utilitarian does the work of the engineer take precedence over that of the architect? In the building of a central station, for instance, no architectural consideration would for a moment hold against the requirements of either the mechanical or electrical engineer in securing the ends of efficiency and economy in operation. On the other hand, in all matters concerning the general aesthetic effect, both exterior and interior, the architect takes precedence over the engineer. The artificial lighting of a building is primarily a utilitarian element, and consequently belongs to the engineer; but since the methods and apparatus used for

the lighting are in themselves proper subjects for decoration, and since the lighting furthermore plays a very considerable part in bringing out the architectural and decorative features, there is a phase of the subject which particularly falls within the province of the architect. The lighting should be both efficient as to quality and results, and at the same time fulfil the requisite demands of the aesthetic; and it is for these reasons that the architect and engineer meet on common ground. The most highly artistic effects are not incompatible with the best engineering practice, but this result can only be obtained by mutual co-operation of architect and engineer, founded upon a reasonable appreciation of each other's view points.

To take up now a few of the specific points. Mr. Jones states that in regard to aesthetic features "the mind instinctively asks, What is the thing for? and unless the answer is forth coming, no amount of grace or ornament can overcome the ensuing feeling or repulsion." Let us apply this formula to the wall bracket shown in Fig. 1. We have there, as he points out, a pleasing combination of curves; the eye follows them with ease—as the common expression goes, "they fill the eye." If we put the question "what is the thing for," the only possible answer is, to hold a candle for the purpose of giving illumination. But it is not holding a candle; it is holding a very clumsy and childish imitation of a candle, in the shape of a piece of opal glass tubing surmounted by an electric lamp bulb. Mr. Jones also quotes the familiar line,

"Beauty is truth, and truth, beauty."

As a whole, therefore, this fixture transgresses both of the laws of aesthetics which Mr. Jones sets forth. It cannot answer the vital question as to what it is for without telling a lie; and no amount of gracefulness of curves or beauty of decoration can atone for this falsehood.

Referring in the same way to Fig. 2, the mind will naturally inquire "What is the ring at the bottom for?"

Mr. Jones.—It is a switch.

Mr. Elliott.—Then I reply that it is a misplaced switch; it should have been on the side walls. The mind does not naturally supply any such reason for its existence.

The lighting of a Cathedral so as to not offend the aesthetic and religious sentiment is indeed a difficult proposition. Still, I am by no means ready to admit that it is beyond the possibilities of illuminating engineering to accomplish this task satisfactorily, even with modern illuminants. It is quite conceivable that the vacuum tube might be worked into a harmonious design, taking advantage of the magnificent vertical lines which constitute the principal element of grandeur of Gothic architecture. Or perhaps a mere change of sentiment may solve the problem. I have in mind the illumination of a cathedral in Chicago that has evidently tossed historic precedence to the winds, and treated the subject in a wholly up-to-date manner. The arches and all prominent architectural lines of the interior are outlined with incandescent lamp bulbs, even to the organ pipes. As a whole, in the vernacular of the day, it has the Penny Arcade "beaten a mile." It only remains now for some other genius to light a cathedral with flaming arcs, which would at least eclipse the Chicago installation in point of efficiency.

Mr. Jones states that a fixture must be proportionately heavy if it is to be used in a room of massive construction. On this point I am inclined to take issue with him. A lighting fixture is not a part of the building, and has nothing to support but the lamps and their accessories. To put a ton or more of metal into a chandelier—as was done in the Pennsylvania State Capitol, for instance—is neither actual nor artistic truth—it is usually plain "graft." It would be quite as logical in my opinion to put legs eight feet high on tables and chairs because they were intended for use in a room with a 40-foot ceiling. It is certain that neither in ancient or mediaeval times was any such view taken of lighting fixtures. The candelabras of ancient Greece and Rome were often beautiful pieces of workmanship, but their design was in strict accordance with their purpose of holding lamps, and bore no relation to the massive buildings in which they were used. The coronas that were used in the early Christian churches sometimes attained large proportions, but they were never "massive," nor clumsy, but proportioned simply to sustain their own weight and that of the lamps or candles which they supported. In every case the builders used the best light-sources which were available, and also used them to the best possible advantage, both from the illuminating and artistic standpoint. There

was no attempt to imitate one light-source by another, and ornamentation was always subsidiary to the usefulness of the light. Now, to say that because the ancients made such good use of the light-sources which they had at their command that we must forever copy or imitate these old and imperfect devices, simply because our remote ancestors used them, is to admit our present entire lack of creative imagination. We have to-day vastly better sources of light, sources capable of infinitely more varied and artistic treatment, which are only awaiting the same spirit of creative art that produced the masterpieces of antiquity to develop aesthetic effects in illumination that will as far surpass those of the ancients as the scientific knowledge of to-day exceeds that of antiquity.

Bassett Jones, Jr.—No one realizes better than I the shortcomings of my paper. Let me say, particularly for Mr. Marshall's benefit that I do not understand why the officers of the section should have selected me to write on a subject of such vital importance for the profession. Yet having once accepted the charge after due consideration I have done my very best to present it in a light best calculated to draw forth discussion. And, lest this be taken as an excuse for over-emphasizing the value of aesthetics, let me further say that I have said nothing in my paper that is not the result of careful deliberation and which I believe to be anything more than the truth. This in reply to Mr. Stickney's charges of "idealism." Philosophically speaking, I am proud to be taken as an idealist, for ideals are the very yeast of life and being, and the man who has ever qualified his ideals by the term "practical" has never handed down to posterity more than an echo of truth.

The criticisms which my little essay has called forth are, I may say, precisely what I anticipated. Their chief interest to me lay in their several view points. To review them in detail would be largely a matter of reiteration of what I have already said, for they serve very generally to emphasize the fact that the attitude of the practical engineer toward any subject not dealing with material things is likely to be narrow and so, productive of error.

In reply to Mr. Marks, let me say, that if the illuminating engineer cares to confine himself to a field where aesthetic is only of secondary importance, then the scope of his work must be ever a narrowing one. The history of the world, if nothing else, must

make evident to us that civilization and interest in aesthetics are synonymous expressions. To make this point evident would lead us into a philosophical discussion, the meaning of which has indelibly impressed itself on every system of reason since the days of Plato. Mr. Marks takes me too narrowly and no doubt this is partly due to my own faulty expression. I realize quite fully that any individual engineer may, if he so pleases, ignore the value of aesthetics and reduce himself to a merely commercial basis without any material reduction or, mayhap, even with an increase, in the amount of his Bradstreet rating. But if this be success, then we count our change in different coin.

I may now answer Mr. Mark's discussion and most of Mr. Elliott's appreciative criticism at once. What is a lighting fixture for? "To enable us to see?"—admitted. What else? Why, to enable us to see with pleasure, and if we cannot see with pleasure, then the device defeats its own ends. But pleasurable seeing is not a mere matter of candle-feet, for in seeing we do not see light—we see its effects, and it is effect for which we must strive. Secondly, we must also see the fixture—and see it with pleasure. Mr. Elliott quotes Emerson, "Usefulness is beauty." So much again is admitted. But again, what is usefulness? Let me refer you to paragraph 23 of my paper. Useful is the thing which produces pleasurable stimuli, and the essence of the emotion of the beautiful is pleasure. Mr. Elliott might have continued his quotation, for as Emerson also says "Beauty is its own excuse for being."

Can you deny that beauty is useful. That it is useful is its own excuse and its sufficient reason. To ask more is to ask the unanswerable. To discuss its limits is like seeking the origin and end of time, for beauty like time is both universal and eternal. And this brings us to a fault to which we are all prone. We seek to define our words in egotistical terms. We confine our viewpoint to that which has bearing only on our own paltry insignificance and so inevitably fall into contradictions because the true meaning of our terms is necessarily as general and as broad as life.

Art is the result of the search for the vital expression of ideals. In this sense it is a philosophical achievement and is the summary of a period of civilization. It is an appeal to reason and so rises and falls with social acumen. It is nursed by a unity of racial

ideals. Its periods of chaos coincide with periods of intellectual readjustment, and so, as a philosophy is the most reasonable expression of the thought of an era of intellectual development, an art is the instinctive expression of the mutual sympathies which unify a people.

But, to return to lighting fixtures. Mr. Elliott says that every object of utility must express a truth. But can truth be confined to the practical end in view? That is to say, is a lighting fixture sufficient unto itself when its object is merely the furnishing of a given amount of light and when it is fashioned solely to this end? I challenge either Mr. Elliott or Mr. Marks to maintain any such thesis, and I again ask for an explanation of terms, for do not all disputes rise from the lack of a definition? If we agree on our meanings, then whence the discussion? Now as to truth. Truth is not merely a matter of what we do. It is concerned both with the means and the end. Otherwise the popular fallacy—any means to an end—holds true. And this, I think, neither of the gentlemen would care to assert.

Do we learn the truth embodied in Greek art merely by a cataloguing of orders and sculptures? Is not the truth embodied in these marvelous productions of this extraordinary people only told when we compare the ideals which these forms express and the means by which the end was obtained? Is not the discovery of the Laocoon itself less important than the determination of the intellectual mood which it embodies? Nay, if we wish to tell the truth, then we must tell it in an intelligible form. If we build a church we must express its objects both in its form and in its appearance. Could the Greeks have worshiped the gods in the theatres of Peloponnesus? Yet, from a purely utilitarian point of view the theatres would have well accommodated the crowd of worshipers and have served their purpose in a thoroughly adequate manner—barring the fulfillment of a desire for suitable form in their surroundings. And this requirement, in his temples as in everything else, compelled the Greek architect to modify the building, its environment, and its furnishings so as to express in every detail the idea of sanctity. He did not light his places of worship as he lighted his houses, for while in his house he recognized the importance of practical utility, in his temples he was rightly willing to sacrifice convenience to the higher ends of sublime impressiveness.

Mr. Elliott expresses some doubt as to the means of day lighting employed by the ancients. Let me set him at rest by stating that the central courts of their houses were open to the sky, while the roofs of their temples, being carried properly by the columnar orders, were raised clear of the wall of the interior space or cella. The Romans, of course, had glazed windows.

The fundamental point I wish to insist upon, even to the extent of reiteration of paragraph 34 of my paper, is the requirement of suitability in lighting as in everything else, and mere convenience and mechanical or electrical perfection must submit itself to this demand. A lighting fixture is but imperfectly useful unless it be suitable to its surroundings, and this, I trust, I have made clear by the meaning of the term. Mr. Elliott denies that a fixture need be in harmony with the architectural design. According to him it should only be suitable to its own immediate purpose. It seems almost unnecessary to reply to this assertion which contains its own unqualified denial. For, if such be the case why should the architect be at such pains to seek an appropriate exterior for his edifice. A plain undecorated enclosing wall pierced at any convenient point for windows is certainly expressive of its own immediate purpose. Then would the plain enclosing walls of a factory be adequate for a church. Nor need we trouble to match our stuffs. Denim makes a very serviceable suit. Why starch our collars when a flannel shirt is so much more adequate and comfortable a garment. If aesthetic pleasure is not a factor in appropriateness, why not serve our potatoes in the pot? and wooden plates are cheap and require no washing! Let us, in fact, at once become barbarians, for between civilization and savagery there is only an aesthetic distinction. Is this not food for thought?

Mr. Marks criticises the bracket shown in Fig. 1. I agree with him that the aesthetic features of the fixture would be lost if the lamps were of high intrinsic brilliancy. Great brilliancy of artificial illumination is almost inherently inartistic, and it seems to me that my paper is largely a brief on this point. In this paragraph Mr. Marks again divorces aesthetic and serviceability. Under the terms of my paper I deal only with "The illumination of structures making an appeal to the sense of beauty," where the illumination must be both useful in the narrow sense and decorative, or, rather useful because artistic and artistic because use-

ful. It is granted that the bracket in question would be totally inappropriate in a stable, and in such a location absolutely inartistic, but in the location for which it was designed it combines the qualities of use and art in its suitability.

The ornament that Mr. Marks criticises in Fig. 2 is a switch handle. Possibly from Mr. Elliott's view point, the designer should have used the usual hard rubber thumb key.

Mr. Marks and I differ on the matter of paragraph 33. I maintain that it is generally necessary to acknowledge tradition in architecture. See "The Nature of Aesthetic" in my paper. Mr. Marks states that it is the business of the illuminating engineer to discard old methods of illumination where new and better ones are available." If he means by "better," the isolated sense of practical utility, then I have already answered him. If he means better in the artistic sense then I maintain that the opinion of the illuminating engineer is only secondary in the premises.

I think Mr. Marks labors under a misapprehension with regard to Fig. 8. This is a view of the dining room of the Grand Trianon and is only a picture gallery in so far as this palace has become a national museum. To disturb its form of lighting would result in loss of historic interest. It is unfortunate that its present use is to exhibit objects of art, for this room is designed for very different purposes and is perfectly adapted therefore. Mr. Elliott criticises the interior shown in Fig. 7 from the view point that it might be used for something else than a reception room. I answer that the Salle des Gardes expresses in itself its purpose, and would be absolutely unsuited to any other use. I admit that if it was used as a study it would have to be differently lighted, but only with a loss of that very unity of design which is good architecture and which is here so skilfully attained.

In paragraph 35 Mr. Marks says that "the illuminating engineer is or should be able to secure the effect by exact and scientific method," which is exactly what I claim. It is the effect, not the quantity, of light that is essential. The "number of other factors" are all important.

In regard to paragraph 38, I can only say that I do not agree with Mr. Marks. This is a question that can only be determined by an actual study of the numerous examples to be found in historic buildings where taste has been the sole quide of the designer. Mr. Marks considers such installations from a view point

different from the one taken by my paper. I claim that illuminating engineering has yet to furnish—nay, is utterly unable to furnish, any data that can direct the ultimate determination of what is good and bad taste. It is the part of taste to furnish the illuminating engineer the data with which he must work.

I heartily join hands with Mr. Marks in any effort to bring about a co-operation between the architect and illuminating engineer, but the engineer must be ready to take his properly subordinate place and receive the data which the architect can alone furnish. I think the gentlemen who have discussed this question from the standpoint of the architect have well borne me out in this. I can only add that the failure of the illuminating engineer to realize the importance of this point is doing much harm to the profession as a whole. It is safe to say that the architect believes that the engineer is seeking to usurp to himself duties which are not his and with which he is usually unfitted to cope.

However, I hold no brief for the architectural profession. The majority of architects do not conceive their designs at all—they draw them. In this country, at least, they share with the engineer a vast inadequacy of education, and if they go abroad they have the last sparks of original genius stamped out in the suffocating atmosphere of the "schools." In sympathies and ideals America is distinct and she, therefore, possesses the essentials of a distinctive art—an art, however, that is at present crushed by the flood of importations. It is because of this lack of a true developed architecture that we are so often groping in the dark, and if the architect himself cannot direct the engineer then the engineer must direct himself, and so I plead for a consideration of architectural principles. The engineer must learn to appreciate and understand the architect's view point.

The architect has need of the engineer's advice, for as Mr. Marks says, the complexity of the means of illumination and the number of illuminants is increasing daily, and consequently greater care is required in selecting and adapting them to their duty. Most of the new illuminants are, however, often impossible from an aesthetic standpoint. Location of lamps is limited to a few well defined points in almost every design, and the demand of the design itself to be properly seen often requires that the lamps be placed where they must be in view and where they themselves form a feature of the design. This often requires that they

be divided into a number of small units of low intrinsic brilliancy, and for this purpose there has yet to be placed on the market an illuminant that can compare with the old tallow candle and its nearest modern equivalent in light giving qualities, the small candle power carbon filament lamp with round frosted bulb.

In reply to Mr. Marks, I can only say that no system of illumination that is not hygienically and physiologically correct can be artistic, for evident reasons. And illumination that is artistic is necessarily good, for it pleases, it enables us to see properly and to advantage; it is suitable, harmonious, and effective. What more it need be I cannot tell. Efficiency and economy begin with the coal pile and end with the lamp. These are a matter of light —not of illumination. The engineer has to deliver a certain quantity of a certain quality of light in a given direction with as little expense as need be. The quantity and quality of light together with the limitations imposed upon him by suitable fixtures form his working data. These are not determined by any requirement of efficiency, but by a very natural desire to have the design look well. If efficiency steps beyond these bounds then it surely must control the design which fixes the illumination once for all.

If I have not already answered Mr. Lansingh's complaint that my paper infers that engineers are necessarily inartistic, let me assure him that I had not intended to convey such an impression. My point is, that in buildings of any artistic pretensions, engineering is necessarily a secondary consideration, and the engineer must be satisfied to achieve the results required, without any preconceived notions of scientific distribution. His science is to enable him economically to furnish a means to the end, and he must have the artistic training to enable him to discern just what he is to achieve.

I wish to correct Mr. Kellogg in one particular. Olive oil burns absolutely without soot or smoke.

Mr. Elliott criticises the statement in paragraph 27 of my paper as to relative proportions, and holds up as a refuting example the delicate work of some Gothic coronas. But then are not the buildings themselves delicate? Look at Fig. 3. Think of exquisite Amiens or Rheims. Where is there any massiveness in design? Is not every effort here devoted to secure fineness of line, refined proportions, lightness of feeling withal the enormous

spaces enclosed. How apt is Goethe's expression of "frozen music" applied to Strasburg cathedral!

Finally let me thank the gentlemen who have shown so much kind interest in the discussion of my paper. I wish I felt that it deserved their remarks. As for our differences, well, there is a good saying that runs—"differences of opinion make horse-races."

THE VARIABLES OF ILLUMINATING ENGINEERING[1]

WILLIAM L. PUFFER, *Member.*

In the discussion of this subject it is assumed that there is no need of taking into account anything to do with the measurements of candle-power, reflection, distance, power, etc. All of these are physical measurements which can be made with very great accuracy as compared with the variables to be discussed, and there can be no question but that they can be measured with an accuracy far in excess of the accuracy obtainable elsewhere in the problems of producing illumination which will be satisfactory for the purposes desired and in the places required.

One of the first questions to be settled is, "What are we talking about?" The question naturally arises, "What is illumination?" It is rather difficult to frame a definition which will be thought satisfactory, and yet almost anybody can say approximately what we mean if he takes time enough. For example—"It is that phenomenon by which non-luminous bodies are rendered able to reflect more or less of the light waves, which may fall upon them from some luminous source, into the eye of an observer and there produce the effect called seeing." As this seeing is almost a necessity for the proper or convenient guiding of other bodily desires, it is naturally to be assumed that it must be satisfactory to the individual.

At this point we stop and consider the conditions as they actually are for the production of good and satisfactory illumination by artificial lights. First, the choice and arrangement of proper lamps, shades, reflectors, positions and the like. Second, the element of satisfaction to the eye which is to do the seeing, expressed in terms of the experience of that eye under other conditions for seeing the same or similar things. It is here that all of the difficulty arises, and it is here that all of the variables come into the problem. It seems to be true that these variables vary as the *nth* power of other variables which also go as the *nth* power; and worse than that, they do not remain constant long enough for one to estimate them even approximately.

It will be interesting to ask ourselves how it is that one sees, and how did one ever learn all about it. It appears to the author

1 Read before the New England Section, December 18, 1907.

that a man does not really see more than one-quarter or one-half of what he believes he sees, and that all of the rest is but a matter of judgment and experience. The eye itself is so poor an optical instrument that it must be aided very much by judgments formed from past and accumulated experiences, joined with the assumed probability that similar experiences will always be produced by similar conditions in the future. A single eye has but two means of indicating the location of an object, one, by changing the size of the pupil in order to vary the amount of light which, emanating from the object, enters the eye; and the other, by a focussing action due to a change in the curvature of the lens. It would be fair to say that, in general, a large pupil is used for near things, as is a shortening of the focus of the eye, while the reverse would indicate a distant object.

These two functions are of but little use when taken alone, but are very materially improved when the second eye comes into play and adds another function, which we call the stereoscopic effect and which is really the establishment and constant operation of a triangulating and range-finding station for unknown distances. Like any possible surveying with so short a base as the distance between the eyes, great accuracy of location becomes impossible after the object has been removed to a comparatively short distance such as a very few hundred feet. The object of this surveying and determination of unknown distances is to afford a knowledge of distance for which the curvature of the lens must be set in order to see quickly, and without the loss of time and effort spent in trying again and again until the right focus is found.

These three fundamental principles are the only means for arriving at information directly through the actions in the eye itself and as the focussing of the eye is a necessity for noting any minute information, it follows that both of the other actions are merely of a helping nature, and if, from any reason, they do not quickly and surely collect information for the guidance of the focussing muscles, then those muscles are obliged to focus at random until the proper range is found. That this causes a very serious eye strain can be easily demonstrated by attempting to see the details of an unrecognized object, of an unknown size and at an unknown distance, by the use of one eye alone. It will take but a single trial to carry conviction.

To these three simple functions we all have added the memory and judgment of years of experience in the combined use of all of our senses in building up our so-called accurate sight by which we instantly translate any combination of light, shade and color. It may be interesting to consider for a moment some of the automatic inferences which are so quickly formed and which directly affect many of the variables referred to in the title of this paper.

We have indelibly impressed upon our mind that a distant object or view is indicated by small visual angles; the axes of the two eyes are parallel and do not indicate a measurable distance, outlines are indistinct and generally wavering, the curvature of the lens is the least possible, the pupil is small, colors are not especially marked, and a bluish or greyish haze is over all. As the range-finding apparatus is out of commission, due to great distance, focussing must be done by the cut and try method, or else by judgment.

We have learned that, in general, shadows of all objects are in the same relative position at the same time, and that it is dark underneath and bright above objects, but that the objects themselves are always bright on the top and side if they are below the eye and dark underneath if they are above the eye. Of especial importance is the fact that the object and its shadow meet unless the object is in space, or is unusually supported, because the relative speed and motion of the shadow is of more use in locating the object that the focussing and distance measuring power of the eye. As an illustration of this, place a small black dot in the middle of a large sheet of white paper and try at arm's length the relative ease and certainty of rapidly touching it with the point of a pin both with and without a shadow of the pin and the hand.

We have learned to judge the distance of near objects by relative positions of overlapping shades and shadows, as well as by what we know of their dimensions, rather than by continually altering the focus of the eyes in the endeavor to find them. The eye takes instant and grateful notice of the help of shadows of all kinds and the moment there are none, or they are in unusual or unexpected places, there is instant eye strain and a feeling of uncertainty and a want of the feeling of "distance."

Bare outline seeing is made use of to an extent not realized,

so that contrast is a necessity, and strangely enough we use the top outline more than we do the lower, as can be noted by trying to read with first the upper and then the lower half of the letters concealed by a piece of card or paper.

The sensitiveness of the eye is changed instantly by any sudden increase of light and remains so for a very material time after the light is again normal, but during this time of dullness of vision nearly all of the common functions of the eye are so far below normal values that sight, for the time being, is lost.

Although the eye is able to adjust itself so that light can be had at very widely different illuminations, it is not desirable to have too great contrasts between light and shade, or too sudden changes from one degree of illumination to another. The reason for this is that the eye becomes slightly blinded by the brighter light, to such an extent that the dimmer lighting is not sufficient for the ready perception of things, and the victim constantly shifts to the brighter place, or desires the continuation of the unduly brighter conditions.

From the very nature of things we form the mass of our experience judgments under the direct or indirect illumination of the sun which is so far away that the law of inverse squares is changed to a law that the illumination is not affected by the distance away from the light source. The single source is mostly out of the direct line of eyesight and when not so, we do not try, nor expect, to see without shading the eyes. The diffused light of a cloudy day has direction and seems to come from a long distance, so that our ideas of shades, shadows and distance are not materially different than on a bright day.

On account of the variations due to education, experience, fussiness, imagination and age it will be found that the eye experience-judgments of a collection of individuals will be very far from unanimous and no one judgment of one individual is likely to be duplicated by himself or others, and especially so if his attention is attracted and an opinion asked.

The author has not been trying, so far, to write a treatise on the eye, or natural illumination, but has endeavored to point out some of the many conditions under which the eye has received its education, as well as to show that personal judgment is the great element which must be taken into account, rather than theoretical and calculated conditions, in determining whether or

not any given illumination is satisfactory or likely to be so. It may be, and is often, true that the judgment which is to be satisfied by a new form of illumination has been deceived, or perhaps injured, by previous conditions over which there was no control, to such an extent that it increasingly demands conditions which will, in the end, work serious injury.

The illuminating engineer of any long experience, who has seen and made a study of these many facts which have made up the experience judgment of his client, and is now confronted with the problem of designing satisfactory illumination, realizes that almost everything is against him and that the final result must be a compromise of a more or less satisfactory nature. The light which he must use will, of necessity, come from luminous points, and at distances so short that the law of inverse squares will be very noticeable over slight differences of vertical and horizontal distance, and each light source will cast its set of radiating shadows which become more and more numerous as the number of sources is increased, until the point is reached when there are so many shadows that the effect is absolute want of any distinctive shadow. At this point the space, as a whole, is uniformly illuminated, but all "distance" will be lost and the eye will have no shadows nor relief to help it in finding the proper point for adjusting the curvature of the lens. When the author enters a room lighted in this way he can feel his eyes "hunting" for the proper focus and becomes very soon aware of eye strain. Probably a part of this effect would be lost in a dusty or smoky room by a sort of grey effect like a true "distance."

One of the very serious troubles is from the great intrinsic brilliancy of all forms of artificial light sources, owing to the very small area from which the light emanates. One of the difficulties of artificial illumination is the masking of this effect by shades and reflectors without too great a loss of the available light. A very good illustration of this was shown by a experiment made in a store a good many years ago (as time goes in this art). An area was lighted both by an equal number of open arc lamps, with either clear or ground-glass globes, and by the then new enclosed arcs with opal globes. Of course, the actual light given by the open arcs was far in excess of that from the others, yet the public in general invariably declared the new lamps gave better light. The simple explanation was that the

open arcs blinded the eyes so much that they could not see, no matter how much light there was, while the large surface of the enclosed arcs at much less intrinsic brilliancy and giving less light looked large and did not blind the eyes. Hence the remark, "What a large lamp that is!" "How plainly we can see by those lamps!"

It is difficult to explain to a client why the common use of glass tops to office desks, highly glazed paper for cards and stationery, inks and pencils of certain colors, and the like, can be made with the side lighting of day, and yet give endless difficulty when the light source is above, and often at just that angle that sends a reflection into the eye of the user. Experience says that these things do not give trouble by day and therefore they should not with any other method of lighting. A careful examination will show, in many cases, that the trouble is partly present by day, and that the user is in the habit of moving slightly as a matter of course, but will not do so when using artificial light.

It is very odd, but we all must have noticed that when there is any fault with artificial lighting the cry always is, "More light, I can't see!" The engineer should quietly point out the lamp shining directly on the reader's face and paper alike, the shaded thirty-two candle-power lamp six inches from the book and the rest of the room dark, habitual work in direct sunlight until time for lighting up and then a few incandescent lamps, and other such usual conditions.

A skilful arrangement of suitable lamps may be made to suggest results which cannot be true in themselves; this peculiarity can be made useful in successive lightings of the same or different objects. It was brought out by some experiments of the author's some years ago when attempting to find what kind of lighting of large drawing rooms would be the most satisfactory to the users. A room about 25 feet by 30 feet was provided with a false ceiling of the height of the new rooms and all varieties of lamps and arrangements that could be readily thought of were installed, with suitable switches for producing any combination desired.

Among the interesting methods were the following: inverted open and enclosed arcs; arcs with many arrangements of globes, shades and reflectors; bands of incandescent lamps over the windows to produce the effect of side lighting similar to the daylight; and individual incandescent lamps with the common types

of shades. It was found, by making use of the room for regular work and with different plans of lighting, that the judgment was, without exception, so biased by the previous illumination that by a proper choice in the handling of the switches any given type of lighting would be selected as the one to be desired. This difficulty was so marked as to interfere seriously with the judgment of the observer, whose opinion was especially desired.

After a trial lasting over several weeks, it seemed evident that by far the great number chose group lighting, with opal screens underneath but free to shine on the white ceiling, thus giving a diffused illumination. When installed, the apparent results were remarkably good, as there was a great flood of light and a high value of illumination on the desks. Soon there were complaints that "they could not see" and "they wanted more light" (note the usual statement of trouble), the illuminometer test showed there was more than enough light, and after a good deal of study the difficulty was found in the use of transparent yellow celluloid triangles and edges to T-squares. These transparent edges, when illuminated by light at certain angles from above, will sometimes show a dark and sometimes a light-colored false edge, parallel to the line to be drawn, which is so annoying that often no accurate work can be done. The complaints were not general, because many of the men used black or wooden instruments and had no such difficulty. This peculiar trouble had not been noted with the triangles when used by the slanting light of day. Experiments showed that the addition of a very little directive light from a two or three candle-power lamp entirely removed the difficulty, but introduced the new one of getting such lamps into proper places, without interfering too much with the use of instruments and large sheets of paper and the like.

The effects produced by the use of light of slightly different color and the fact that there are so many people who do not have normal color judgment, will show in the comparative opinions of the satisfactory amount of light falling upon a given place or object. The slight apparent greenish tinge of the tantalum lamp will make trouble if colored goods are viewed by it and then by the light of a common incandescent lamp of low efficiency, and the difference can readily be seen with the high efficiency Gem lamps. What a really color-blind man could see in a room lighted by either the mercury arc or the yellow flaming arc is a matter

of conjecture, and it is very doubtful if any value of foot-candles, as determined by the normal eye, would be satisfactory.

The unfortunate wearer of spectacles or glasses is another person whose eye judgment will be at variance with normal values, on account of the absorption of the light coming through the glass and the larger amount of stray light reflected into his eyes by the back surface of the glass. One becomes used, in a way, to this effect, but it still remains as a conflicting element in his interpretation of what he sees, and a brighter illumination of the surface looked at will be required than if glasses were not worn.

It may seem strange to be told that the amount of light required by a right-handed or a left-handed person is different, but if it be remembered that the average lighting is arranged so as to come from the left, it will naturally follow that the hand of a left-handed man will be in his own light. The usual way of meeting this peculiar condition is the lighting of a reading desk or office desk with one lamp in the centre, or of a square-topped desk for four people with a central standard. In these cases it might be desirable that alternate readers or clerks should be left-handed!

At some time or other the engineer will find that purely personal physical comfort will have a great deal to do with the satisfaction of a lighting scheme; as for example, objection is rightly made to the use of lamps hung just above and back of the reader's left shoulder, because the heat of the lamp causes a headache. While such things are not strictly illuminating engineering, yet they will make a great deal of difference in the final opinion of an engineer's work, and should be constantly in mind.

There is much to be said on the actual amount of light really required for the solution of any given case, and too often the variable elements are not taken into account. Too much light will be demanded by those who are relatively new or unskilled in the work they are doing; it is well known that when the eye has been trained in its duties there is much less real concentrated effort required than when it is receiving its education. On the other hand, there must be a greater amount of light available when the eyes cannot have any relief, owing to the kind of work being done, as "satisfaction" will demand that the eye can quickly see and recognize small shapes which must be clearly brought into focus before there can be recognition. Such work might be

bookkeeping of the kind that requires rapid selection of figures, proof-reading, mechanical drafting, use of fine instruments and the reading of fine scales like micrometers.

There is nothing to be done in such cases except to supply a plenty of distant or diffused light with directive shadows and then for best effects advise the use of eye shades. These latter devices will, in many places, produce an effect equal to an increase of one-half or more of the light, by protecting the eye from the blinding effect of a lot of overhead lamps, or other brilliant ceiling illumination.

The last of these unknown variables to be met and overcome by the consulting illuminating engineer, is the criticism of the man who is not open to conviction because he does not want to be convinced, as he has some interest in some other plan which he thinks would produce better results. As there can be no after remedy for this sort of criticism, it should be expected and looked for as a matter of course and its possible effects anticipated to see if there can be any way of overcoming it and preventing it from producing any permanent injury to the satisfaction which should be enjoyed from the lighting. Probably the safest way to overcome this criticism is by means of the preliminary study which can be so carefully made as to leave evidence in the minds of those most interested of the desirability of the means selected. A good preliminary discussion of the probable results to be expected, and a pointing out of the difficulties to be overcome, as well as a clear showing that the daylight illumination has its defects, will go far to disarm the man who does not recall the saying that it is easier to ask questions than it is to answer them.

DISCUSSION.

John Campbell.—I think as well as variables there is what might be termed individuality. As far as the question of lighting is concerned, I doubt if any ten men that you might pick at random would agree that any particular lighting installation was correct. There would be the individual criticism of the thing. I belive what Professor Puffer has said about too much or too little light in offices. Often, if you could substitute smaller lamps without the people knowing about it and perhaps get the clerks to change their positions in some instances in the office, you would

get credit for doing wonders with the lamps. I sometimes think it would be a very good thing to leave off the candle-power measurement of the lamps. As long as one is marked 32 candle-power, it is considered all right. It would not, in many cases, make any difference whether it was an eight or a sixteen, as long as it has thirty-two stamped on it. It is the individual judgment of the man more than anything else.

N. W. Gifford.—I think it is very true that we are frequently trying to use a great deal more light than is best for us, and are dissatisfied without knowing what the trouble is, thinking we have not light enough. I have noticed it in my own case.

B. B. Hatch.—The committee appointed to investigate illumination intensities has reported that the proper illumination is about two foot-candles on a school room desk. The matter of variables has entered into the question very largely. I happen to know that the five members of the committee who reported on the question had quite different opinions at first, but it was finally decided that two foot-candles was about right.

Mr. Campbell.—Regarding too much light, I do not know whether the reason why nothing more has been done with the Welsbach lamp is due to mechanical reasons or not. Of course there is a smaller unit, but practically you have got to use the one size of burner.

T. A. Curry.—The manufacturers of the Welsbach lamp are making mantles burning from eight feet of gas down to one and one-half feet of gas an hour, depending entirely upon the kind of glassware used. We manufacture a mantle that consumes one and one-half feet of gas an hour, and gives approximately thirty candles, and that is, I think, the smallest mantle made.

The Standard mantle is three and one-half inches high and gives approximately twenty candle-power to a foot of gas consumed. The quality of light depends altogether upon the quantity of cerium used in the mantle. If a yellow light is desired, a greater quantity of cerium is used, but if, on the other hand, a while light is desired, such as is used in photographic work, the quantity of cerium is diminished.

It has been our experience that the demand is for a white light, but we are gradually educating users of Welsbach mantles up to

the yellow standard. Mantles made at the present time cannot be considered either white or distinctly yellow, but are of a happy medium; but, as I have stated before, we hope in a short time to have educated the people up to the use of the yellow light, as we feel there is no question but what it is a much pleasanter light to read by and much easier on the eyes.

Dr. Louis Bell.—I think Professor Puffer has done us a good turn in calling attention to the subjective factors in lighting—how great they are, etc. There is, however, one broad fact based perhaps on subjective facts which he ought to remember very carefully, and that is that uniformly distributed illumination does not get one out of the difficulties which one encounters. It is a comparatively easy matter to form an approximate idea of the amount of light, in foot-candles, that is needed for any particular work. It is also a comparatively easy thing, with the resources now at our command, unless a room is very peculiar in dimensions or in finish, to provide approximately this required amount of illumination upon the working plane and to hold it with very good uniformity over the surface. But that does not guarantee satisfaction in that place, even assuming no personal idiosyncracies enter into the question. In other words you can get, we will say, two, three or four foot-candles, which is about the usual range, on a plane thirty inches above the floor in this or any other room. In so far, the illumination is quite ideal in quantity. You can also arrange the light so that there will not be objectionable cross shadows, but you cannot overcome the efforts of the young man devoid of understanding who insists upon putting his back to the light and pushing his desk where he will get the light over his right shoulder or sitting with a blinder over his eyes and poking it down over the paper so as to cut off what little light might otherwise come to him. You cannot, in other words, prevent a man misusing any kind of light, natural or artificial, however uniform or however adequate it may be. That is one of the most serious things confronting us from a practical standpoint. You can give a man in a counting room, for example, superb illumination, and if the man insists upon putting his clerks where they have their backs to the light, where they write with their pens in the shadow of the hand and do other illogical things, you cannot get satisfactory results. That is simply the everlasting contest of improve-

ment against human stupidity. Sometimes you find a man who is willing to do all he can to utilize his illumination if you will do what you can to give him the illumination. Then there is no such trouble. I had a couple of cases within the last year which point the moral here. Both were rooms where a considerable amount of clerical work had to be done, and clerical work is harder than it seems to be, on account of the habit of writing with a crow quill pen, with ink which is a pale blue when first used and which may possibly turn black if kept on file long enough, etc. Part of the trouble also comes from the use of colored papers to which Professor Puffer has alluded,—blue, yellow, pink and other colors. All these things make it difficult to light a room anywhere for clerical work on account of the extraordinary conditions. Pencil notes made with hard pencils on manila paper, etc., constantly bother a man who really wants to see quickly and promptly the things which are of vital importance to him. That puts the counting room almost into a class with the drawing room, as regards amount of light required. In the two cases to which I was referring, one was a room where a lot of this fine work had to be done and which was run by a man who was thoroughly interested in getting good lighting. The lighting to start with was uniformly distributed and sufficient in amount—reasonably good, steady, uniform illumination—and a very small amount of attention in keeping the men in proper positions, and shifting the desks so that they came in proper positions solved the problem entirely. The other room was bossed by a man who flew into the air with excitement if you suggested that it might be a good idea to use black ink, or if you intimated that a couple of clerks who had plate glass tops to their desks should sit on the opposite side of the desk. "Oh, no, they could not do so. It would upset the entire establishment if they moved to the other side of their desk. They must have the glass there or they could not use the desk," etc. The result was I do not believe that room will ever be properly lighted on account of the man who runs it. Nevertheless, the illumination itself was substantially the same in both rooms; to wit, good illumination properly distributed. It is that personal factor which makes the work of the illuminating engineer so difficult. People are governed to a large extent by certain superstitions. The idea that because the light is very bright it is good light, we are gradually getting shaken out of us,—

rather more rapidly I think than one would expect, but the notion that the only good light is light which is immediately over the work is one that the people are very slow to throw over. The desk lamp of thirty-two candle-power is a mighty good thing to get rid of. I think the chairman's suggestion of taking off the lamp labels would, in nearly every case, obviate the difficulty, and the man would be just as happy as with the big lamp, provided he did not know of the change. That subjective factor is constantly a troublesome one.

One of the things which we really have to meet, however, which is not in the subjective class, was brought strongly to my mind by a remark of Professor Puffer's, and that is the conditions we have to meet just as a room is passing from natural to artificial light. Two things are going on there, both of them bad. In the first place there is an abrupt change in the direction of illumination. If a man had the shadows comfortably arranged with the natural light, they will be reversed with the artificial, or vice versa. In any case the period during which the change is taking place is embarrassing. It is best met by pulling the shades. People often do not think of this, though that is the simplest way to meet that particular difficulty.

The other thing to be conquered in the same way is the actual difference in color between the two lights. Skylight, particularly when the direct rays of the sun are far from the building, is much bluer than any artificial light. The difference in color is very radical. If you put a pencil on the desk where the artificial and natural light come from two directions and watch the shadows it will be seen. The result is that the eye hunts for a focus between the two focal surfaces, one of them determined by the short wave lengths of the skylight and the other by the longer waves which come from the artificial light. The difference in focus between the dominant rays in the two cases may be enough to keep the eye undecided whether it shall push the blue rays into focus or the other ones, and there is a constant tendency to "hunt" which, in addition to the difference in direction, makes a very distressing condition. The only thing to do is either to pull the shades or provide enough artificial light to drown out the other light. Sometimes the desks and tables at one end of the room only would need artificial light at first. Those near the window would get natural light for some time after the

others. Perhaps in this case the best way is to provide enough light of an artificial character to drown out the other when the change in quality is first taking place.

Professor H. E. Clifford.—Professor Puffer states in very clear terms the fact that illumination is concerned with two distinct effects, the physiological effect, which is merely the reception of light waves in the eye, and what is more important, the psychological effect, which is judgment as to the effectiveness, the value, the character, the satisfaction of that particular light. I say the psychological effect is much more important, and I think we all admit that to be the case. It gives rise to these variables of which Professor Puffer has spoken. I have in mind a drafting room in an educational institution where the students are particularly insistent on securing proper lighting conditions for working. Fifty candle-power lamps were removed and thirty-two candle-power lamps of the same type were used in replacing them. The person in charge of the room received for a number of days frequent statements that it was an imposition to ask students to carry on drafting with such reduced illumination. The matter came to the attention of the professor in charge of the illumination and he, realizing the phychological effect, replaced those thirty-two candle-power old style lamps by thirty-two candle-power Gem lamps with satisfactory results. The Gem lamp had about the same volume, to the eye of the student, as the old fifty candle-power lamp. The idea was that they were used to seeing a certain volume of bulb. That volume of bulb they thought must of necessity give a certain amount of light. The psychological effect was necessary there to give satisfaction.

Professor Puffer said it was rather difficult to define illumination. I think I should differ with him on his definition. It seems to me he does not discriminate between illumination and seeing. Illumination, as I look at it, is the amount of light any object receives expressed in proper units. Seeing is the power to discriminate between two objects. This question of terminology in illuminating engineering is most important.

I was struck also with the statement in the paper as to the inability of the eye to judge of distances unless by comparison with some background. I think we are all familiar with the size of the rising moon as compared with the moon in the zenith.

We know that the relative angle subtended does not give us any such difference as we apparently see. I am much interested in the question as to what influences the ease of determining position by using the shadow of an object.

Professor Puffer.—In case of a shadow you do not take the trouble to focus. In the other case you must focus.

Professor Clifford.—A bright light in any particular part of the room and the rest of the room dark, is a condition that is being more or less discarded. Only a few years ago it was not uncommon to find a very bright light over the books or desk and the rest of the office would be in greater or less obscurity. The effect undoubtedly is that the rapid change of size of opening of the pupil as you look from the brilliantly illuminated portion into the dark areas is the cause of fatigue which thereby results. I was glad to hear Professor Puffer speak of the glazed papers. I had some experience with these for a number of years in my work, with constant protests. Whether glazed papers were cheaper I do not know, but at all events in blocks for scribbling which one is apt to use, the glazed paper produced an effect of fatigue which brought on in my own particular case distinct headache. Working under exactly the same conditions, with the same illumination, the same number of hours per day and with no very great difference in the age of the worker, I find there is much difference from this cause. I think the use of glazed papers is very harmful.

I am interested in Professor Puffer's suggestion as to what the effect would be if a color-blind person were placed in a room lighted by either a mercury arc or a yellow flame arc. I believe the effect would be about the same as that on the normal eye. If you take any line spectrum such as that given by these lamps the effect of contrast is very much the same for the red blind as it would be for the normal eye, though not of course for the green blind.

I also heartily subscribe to what Professor Puffer says as to the distinction between selecting and getting a general idea—of merely taking a general look or of recognizing details. The difference is very marked indeed in the character of illumination required. I have noticed that especially in the laboratory in the reading of verniers. You may take the scale of a vernier and

get a general idea of it with any sort of illumination, but if you have got to tell whether it is some particular fraction of an inch or of a degree the character of the illumination must be much superior to that required for a general setting of the scale.

Dr. Bell.—One thing is the question of habit in ease of reading. I think we see the difficulties which come from observing unusual things when we begin the study of German or of Greek.

Professor Puffer.—Reading a German paper or any unfamiliar form of type is especially hard because we are not used to gauging it at once and it requires exact concentration to make out the form. Another very interesting instance showing the failure of stereoscopic vision and the attempt of the eye to get this under certain circumstances can be observed if anyone looks into one of the old-fashioned panoramas. Go into one of those where you have real cannon and stuffed horses in the foreground fading off into the distance apparently but really into the painted images of such things, and the eye gets a terrific strain. It travels up very well on the real thing and then vainly endeavors to find something to fix on in the painting, and the effect is quite distressing.

Professor Puffer.—That effect works two ways. If the distance measuring does not extend more than a few feet, what difference does it make whether we see an object or the imitation, provided the imitation is at such a distance away that the effect is the same. You are going to say that the eye does focus further than the distance measuring device.

Dr. Bell.—But also the distance measuring device works over comparatively a short distance and then tries to continue the same process abruptly on the picture and fails.

Professor Clifford.—I think some of it is due to the lack of a proper vanishing point. You have no fixed vanishing points as they actually exist in nature. As you look at any landscape you have a vanishing point. The cyclorama must have a vanishing point on the arc of a circle. You look at it and you are immediately lost for a proper vanishing point to produce the effect due to conveyance of the axes of the eyes.

Professor Puffer.—I would say that one of the objects I had in writing this paper was deliberately to call attention to the

fact that the element of satisfaction to the user is about fifty per cent of the work of the illuminating engineer, and the satisfaction of the user is expressed in terms of his experience under which he has previously seen these things, and if he has always seen a thing black on one side and white on the other, he does not know what he is looking at if you reverse the colors. I have seen some very strange experiments showing the difference in the appearance of things when the direction of illumination is altered. You can see that in some mills, noticing the difference between daylight work and night work. It is not the same place in appearance and is so different sometimes that you would hardly recognize the place. Some ceilings come out at night. In the daytime you cannot see them. By daytime the floors are very plain in certain places. By artificial light they are very likely to be plain in all places, and that affects the eye in what I have termed after considerable thought "previous eye experience judgment." That is what we work by. Often you really do not see. You simply realize that a condition has happened and you know from previous experience that a certain thing is there.

J. S. Codman.—I once asked a printer if the various glazed papers are used so commonly because they are cheap. He said no, that they are expensive papers. As far as I could make out from him, the only reason for using them, unless people like them, which I cannot imagine, is that they take cuts well.

Mr. Hatch.—I would like to ask Professor Puffer if the psychological effect spoken of has been taken up in connection with indirect forms of lighting—that is lighting by reflection? That effect has been spoken of by the committee which has recently reported on schoolhouse lighting, saying that any form of illumination realized by means of reflection, or a fixture throwing its light against the ceiling and from there down is undesirable.

Mr. Hatch.—A two foot-candle indirect illumination does not seem to satisfy as well as one foot-candle with direct lighting. You cannot see the source, and it is the psyohological effect of that kind of light.

Professor Puffer.—I think off-hand I should dispute it.

Professor Clifford.—I think there is a general feeling among observers that where one is receiving any sensation, the best satisfaction requires that the source of that sensation should be visible. You know, for example, in listening to an orchestra there is not the same satisfaction when you cannot see the performers. It is not the mere kind of tone but the association of the actual sensation with the method of its production.

Dr. Bell.—The whole point is this, in the report of the committee. The term "indirect lighting" as used by it means lighting which is shadowless. I think there is an absolute confusion of ideas in using this term to signify completely distributed indirect lighting. There is no question but what shadowless illumination is more trying than other illumination.

Mr. Hatch.—I have been inclined to think that the psychological effect is due to the highly illuminated ceiling.

Professor Clifford.—I think that is right. A highly illuminated ceiling rather clashes with one's judgment of what its *distance* should be. It seems to bring it too near.

Professor Puffer.—I think also that our experience is that the bottom of things ought to be black.

Professor Clifford.—Anybody who objects to the ceiling being too strongly illuminated will find that it is perfectly satisfactory with eyes shaded.

Mr. Hatch.—In the schools the pressure in the head spoken of has everywhere been complained of.

Mr. Puffer.—I would like to see an instrument which would measure the pressure on a man's head when he is thinking, and note the change in pressure when a shade is put on the eyes. I think it would be considerable.

Mr. Codman.—Don't you think the eye shade is a remedy that is worse than the disease?

Professor Puffer.—It is a nuisance, of course, but it is a matter of choosing the lesser evil sometimes.

DISCUSSION BEFORE THE NEW ENGLAND SECTION ON "FIXTURE DESIGN FROM THE STANDPOINT OF THE ILLUMINATING ENGINEER," BY LANSINGH AND HECK, NOVEMBER 5, 1907.

B. B. Hatch.—Mr. Lansingh has directed our attention to the improper use of green flashed shades in connection with library table lighting. We have had considerable experience in this class of work, and have found the green flashed shade more desirable than the McCreary frosted bottom, for two reasons, one of which is the wider distribution of light obtained from the green flashed shade, and the fact that the McCreary shade catches and holds a great deal of dust. I agree with Mr. Lansingh that the McCreary shade is more ideal, but in order to light a standard library table it would be necessary to install more than two fixtures, as we now do. Library authorities would object to having any more of the table space taken up with fixtures.

Artificial lighting has very little to do with the eye troubles in children as they develop while the child is very young, say between the ages of seven and nine, which is before the child begins to attend night schools. It is my opinion that more defective vision is caused by the uneven daylight illumination than is generally realized. An average size class-room may have seven rows of desks, and in most cases will be lighted from a single row of windows on the left. The child in the sixth or seventh row gets about one-tenth the illumination that is received by the child in the row next to the window. This may be sufficient in some cases, but many rooms are so situated that daylight is partially cut off at some part of the day and then the illumination is altogether insufficient and it is largely from such cases that defective vision originates.

H. T. Sands.—There is one very important factor in fixture designs, speaking now from the residential standpoint, which I think has been overlooked in the presentation of this paper, and that is the householder himself, or to be more exact, the householder's wife. We find that she has some very decided ideas of her own as to what she wants in her house, and we can talk efficiency all we please, unless we can combine beauty with

it, she will not have it. There is no doubt but that the prismatic shade has done a great deal for us in the field of store and auditorium lighting, but I have failed to find it of much value in residential work. I fear that our prismatic friends have gone to the other extreme and have sought for efficiency only without any regard to the beautiful.

W. H. Blood, Jr.—I do not think there is any apparatus in use in connection with electric lighting which has been so much neglected as the design of fixtures. In the catalogues of the best fixture manufacturers to-day, the standard fixtures are almost identical with those made ten or fifteen years ago. Fixture manufacturers do not seem to have made any progress at all.

It seems to me that great many illuminating engineers have erred by trying to produce a uniform distribution of illumination in residences. Personally, I believe that that is the last thing we should strive for. The beauty of a landscape depends upon contrast between light and shade. No room in a dwelling house is attractive which is flooded with a glare of light.

The placing of fixtures in the centre of a room is undoubtedly the most economical way of lighting a room, but it gives this unpleasant glare that I have spoken of and makes it almost impossible to sit and read with any degree of pleasure in any part of the room.

The placing of lamps in suitable brackets on the side walls is to my mind a better way to light a room. The light, of course, should be properly shaded or the lamp should be enclosed in ground glass globes. Softness of light should be striven for. It is undesirable to use lamps which have high intrinsic brilliancy.

Mr. Lansingh has called attention to a fixture which is used in the Hotel Astor, New York City. He says, "this is undoubtedly one of the most economical methods of lighting a room." I agree with him, but at the same time I believe it is most unsatisfactory and inartistic. I have a fixture of this kind in my own living room which produces very harsh and unpleasant lighting effects. My plea is for the elimination of such fixtures as this and the recommendation that a great deal more attention be given to the design of proper side brackets and their careful installation.

W. E. Clark.—The illuminating engineer must point out the essential characteristics of fixtures that will properly illuminate

a room, and the designer or artist should endeavor to make these fixtures most pleasing in outline. One of the members this evening has said that the architect rightly requires a wall bracket to point upward in a colonial cottage, even though the room under question would be better or more economically illuminated were the bracket to point downward. Is this a fact? It is true that when colonial architecture was first developed that the oil lamps of various sorts and the candles threw their flame and light largely upward, but when the old passes away, why should the new of necessity imitate the old, especially if the characteristics of the new are such as to be of greater value if used in a new way?

There is a tendency to light many fine rooms by wall brackets, even though it is very uneconomical compared with ceiling lighting. It has been pointed out repeatedly that central ceiling lighting is unnatural compared with daylight, and is unpleasant and trying to the eyes. But we should remember that there is an alternative, that of using several ceiling lamps. By using box clusters or fixtures in the four corners of the ceiling one could get a suitable illumination for reading. Nor does one have to depend upon ceiling lighting nor wall lighting for illumination for reading, for the portable reading lamp is superior to either.

In decorative lighting I have noticed an increasing tendency toward using many handsome portable lamps arranged on tables at sides, corners, centres, and in fact any convenient point in a room, wired from base and floor receptacles.

J. E. Livor.—So many remarks have been made against the fixture man, and in a manner showing gross ignorance of the conditions which the fixture manufacturer has to meet, that I feel it necessary to say a few words in his behalf. I do not blame the architect for demanding fixtures which are architecturally correct. In fact, the fixture man is heartily in sympathy with anything of this kind. But it is very evident from the discussion that the fixture man and the illuminating engineer are at considerable variance, the illuminating engineer being, apparently, as far ahead of the times as the fixture men with his "old fogy" ideas is behind. Therefore, it seems to me that if the fixture man came up to the mark and the illuminating engineer left his ideals and came down to the mark, we would meet at a happy

medium which would result in a combination of illuminating efficiency together with artistic and correct lighting structures.

From the remarks made by many of those present it would seem impossible to get scientifically correct illumination from a chandelier with the lamps turned up. This is a fallacy of the worst kind, as some of the best illuminated rooms have upright arms on the chandeliers. Further than that, it is a well-known fact that our ancestors did not burn candles upside down nor did they burn oil lamps upside down. The illuminating engineer in his ideals will say that it is not necessary to do what our ancestors did as we are in advanced times. This is correct from every other standpoint but the architectural, and in a great many cases the fixture man would advocate lamps turning downward, even on an old classic fixture; but on the other hand, if you enter a building where thousands upon thousands of dollars have been spent to obtain an effect in a certain period, we will say for the sake of argument, Colonial—does it seem exactly right to put the lighting fixture in the centre of the room, which is just as important to the detail of the room as a piece of furniture, and turn it upside down, with either candle or oil lamp effects coming from each arm, or would it be proper to change the period of the fixture to *L'Art Nouveau*, so-called, so that we might obtain the proper effect of illumination, when sufficient illumination can be obtained with the arms turned up and everything be in harmony with the architectural detail of the room?

One of the speakers mentioned the fact that he could not go around to any fixture house in the country and find six fixtures that were properly constructed from the illuminating engineer's standpoint. Let me add—If any dealer had more than six of these fixtures along these lines, he would be obliged to go out of business. This may seem unnecessary harsh, but I think it better to deal with cold facts rather than pleasant words which mean nothing. Further than that, several designs shown in the paper, which are termed good designs, certainly would not grace fixture show rooms.

It is a very rare thing to go into a house or a building under the existing conditions which may be called poorly illuminated. It may be expensively illuminated but the fixture man always considers the matter of giving sufficient light. In residence lighting we meet a great many people who insist upon having nothing

but a dull glow of light throughout the various living rooms. From an artistic standpoint this is correct, but personally I do not belive in having dull lighting in any room, neither do I believe in having sunshine at night. But there is a happy medium to be reached and that can be only done when the illuminating engineer realizess the obstacles which the fixture man has to overcome, and, instead of telling him what to do from away off at a great distance, comes down to his position, placing himself as the fixture man is placed, and then with his scientific knowledge works out the problem along these lines.

John Campbell.—In probably no other society than that of the Illuminating Engineering Society is the question of responsibility for results more frequently passed on from one to the other. For instance, the fixture dealer, the moment a criticism regarding the lighting results of a building arises, very calmly says, "Its up to the architect." This to a certain extent may or may not be true, but it is a conspicuous fact that the fixtures as sold to-day are mere reproductions of those of antiquity. I am not speaking now of the class of fixture that means a large expenditure of money for special results, but I mean the average moderate and low priced electric fixture of to-day is nothing more than a reproduction of the older form of gas fixture, slightly adapted to electric use.

Now this is a matter that the fixture dealer is responsible for himself.

Our modern hotels are a shining example of poor fixture design, and I mean by poor fixture design that the fixtures do not meet the requirements for which they were intended. Go to a hotel and have occasion to read or write in your room and in nine cases out of ten, you give it up either from eye ache or else in sheer disgust because of the fact that your light is anywhere but where it can be used.

R. C. Ware.—I agree entirely with Mr. Blood as regards the very unpleasant effect of a room lighted by a chandelier in the centre only, when this room is to be used for reading or study. The room thus lighted is undoubtedly fully and economically illuminated, but I think in general a better result is procured by the use of a prismatic ceiling hemisphere, which is a real boon to the ordinary lighting of the living room.

You cannot, on the other hand, obtain really satisfactory results from bracket lighting only, and for the ordinary living room I advise a combination of these methods. As regards the problem given the fixture designer by the architect it seems to me it is up to the designer primarily to procure satisfactory results, from the point of view of illumination; he must adapt the design to these necessities first, and with the architectural requirements as a secondary consideration only.

With the present methods and means at our disposal, I believe that we can obtain almost any desired artistic result without interfering in the slightest degree with the efficiency of the fixture. In the case of the classical building referred to, the fixtures could be made in the shape of torches or tripods, etc., and yet by means of suitable reflectors give a suitable illumination. The architect is not, it seems to me, at fault in this regard.

As regards the lighting of schools; I think most of the trouble with the eyes of children should be treated by doctors and parents at the home where the trouble originates. On the other hand, school room lighting should be given the greatest attention; and in the case of the deep room lighted by windows on one side only, the side away from the windows is unduly dim and artificial light should be used for that portion of the room. The quality of light used must, of course, approach that of daylight as nearly as possible, the incandescent gas lamp being the most serviceable in this respect.

In closing, I should like to call the attention of the members to the fact that architects and illuminating engineers when laying out installations should realize that, with modern methods, gas can be adapted to practically any desired form of fixture. I have been looking over Mr. Lansingh's article, and with only two exceptions—the ceiling hemispheres and the lamp at a marked angle—I see no fixture to which gas mantle illumination cannot be adapted, either with the upright mantle or the exceedingly efficient and satisfactory inverted burner.

V. R. Lansingh.—I should like to emphasize the question brought up by Mr. Hatch, of the necessity of using some form of mica gasket or asbestos washer in all pendant closed globes to prevent the entrance of dust. In many forms of fixtures as made to-day, the husk which supports the globe prevents the en-

trance of dust, but where such globes are supported, as is done in a large number of cases, by a simple holder, there is nothing to prevent the entrance of dust which collects at the bottom. This, in the first place, looks bad and second, very materially reduces the efficiency.

Referring to the question of school room lighting as brought out by Mr. Hatch, I agree with him that undoubtedly a good deal of harm comes to the eyes of school children through poor day-light illumination and that this harm is further enhanced by the generally poor illumination which is furnished the ordinary child for study at home in the evening. At the same time, we are more or less ruining the eyes of the adult who attends night school. In the city of New York no effort has been spared to obtain good lighting by day, but no study apparently whatever, has been given to artificial lighting. In all of the rooms I have seen the artificial lighting is obtained by a number of clusters of bare lamps covered with a flat porcelain shade, hung about six feet six inches from the floor, and so placed that a student in looking toward the front of the room must necessarily look directly at the bare lamps. It would be rather hard to conceive of a condition which could be worse as far as the effect on the eye is concerned.

Mr. Sands spoke of the difficulty of getting the householder's wife to look at the problem of illumination from the standpoint of economy. I thoroughly agree with him that this is a difficult task, for, as a rule, the only points which she will consider are the artistic. Nevertheless, by the use of a certain amount of diplomacy, it is possible, in many cases, to design illumination which will fulfil her idea of the artistic and not be uneconomical.

Take for example the question of lighting a bed room. One of the best schemes for lighting such a room that I know of, is that used in the Astor Hotel, New York, where the main lighting is done by a ceiling cluster with concentrating prismatic reflectors which give good general illumination, but at the same time a sufficiently concentrated light directly underneath to enable one to sew or read easily. Two somewhat similar fixtures are placed over the bureau and by means of the white cover on top give good illumination, not only on the top of the head of a person standing in front, but also reflect sufficient light under the chin to make shaving an easy task. In addition, there is a portable lamp for

reading in bed, placed on a small table and shaded with a silk shade. Even ladies who have critically examined this lighting have pronounced it satisfactory to their artistic sense.

Generally speaking, however, the lighting of bed rooms, especially in hotels, is about as poor as one could imagine.

With reference to the point brought out by Mr. Blood as to the fixture dealers being hide-bound and behind the times, I must say, that, in general, I thoroughly agree with him. It would probably be impossible to go in any fixture dealer's store in Boston and get them to point out to you a fixture, even of the simplest character, which was designed primarily, or even secondary, to give good illumination. The fixture dealer is, as a rule, apparently bound by only two considerations: the amount of metal which can be placed in the fixture, or the artistic effect which can be obtained, apparently overlooking entirely the fact that the fixture is primarily designed to give illumination.

With further reference to the point brought out by Mr. Blood regarding centre fixtures and side brackets, I would state that there are advantages and disadvantages to both methods and that probably a judicious use of both is most satisfactory for house lighting. Undoubtedly the centre fixture is the more economical, inasmuch as the rays of light pass through the room before reaching the walls where they are largely lost by absorption; while in the case of brackets, nearly one-half of the light strikes the walls where it is largely lost. Again brackets are especially hard on the eyes if one has to face them, and it is difficult to place them in an ordinary living room in a satisfactory manner.

I thoroughly agree with Mr. Levor that in a great many cases the fixture design must be architecturally correct and the illumination must be subordinated to the artistic requirements. The trouble is that, as a rule, the architectural design is given the only consideration, although it is possible, as I have endeavored to show to-night, to obtain in many cases a design which may be thoroughly in keeping with the room in which it is placed, without sacrificing good illumination.

With reference to the point brought out by Mr. Ware, almost every fixture shown in to-night's paper could be adapted for use with the inverted mantle burner with but slight modifications.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. FEBRUARY, 1908. No. 2

At a meeting of the Council held on February 24, Dr. Louis Bell stated that on his election to the Presidency of the society, the office of the Vice-President representing the New England Section had become vacant, and that Mr. W. D'A. Ryan, as a senior Director, and a member of the New England Section, had succeeded to that office. A motion was made, and duly carried, that the election of a Director of the Society, to succeed Mr. Ryan, be deferred until the next meeting of the Council.

Announcement was made by President Bell that Dr. A. S. McAllister had accepted the appointment to the Chairmanship of the Committee on Editing and Publication for 1908, succeeding Prof. Wm. Hand Browne, Jr.

Upon the recommendation of the President, and the approval of the Council, it was resolved that the members of the present standing and temporary committees be reappointed for the term of 1908.

The Chairman of the Finance Committee presented the final report of the Committee for the fiscal year 1907. This report was accepted by the Council. A committee consisting of the Treasurer, Secretary, and Finance Committee of the Society was appointed with power to arrange for properly closing the books and accounts for the year 1907 and opening them for the year 1908. Bills payable were reported by the Finance Committee, and a motion was carried that, when duly audited by the Committee, these bill be paid.

It was stated that no report had thus far been received from the Committee appointed to investigate the matter of the discon-

tinuance of the Pittsburg Section. It was decided that the matter of the withdrawal of this Section be taken up for final decision at the March meeting of the Council, and that the Committee appointed to consider the matter be so advised.

By vote of the Council, the following forty-two men, whose applications had been properly endorsed and approved by the Board of Examiners, were declared elected:

ARMSTRONG, G. W., Manager, Chicago Branch, Excello Arc Lamp Co., 118 West Jackson Boulevard, Chicago.

BARDEN, HENRY C., Chief Electrician, State House, Boston, Mass.

BEAN, J. G., Meter Tester, Phila. Elec. Co., Philadelphia, Pa.

BIXON, J. G., Sales Manager, Cleveland Gas & Elec. Fixture Co., Conneaut, O.

BOYLE, FRANCIS J., Inspector, Lamps & Gas Department, N. Y. City.

CASCADEN, A. J., Assistant Meter Tester, Phila. Elec. Co., Philadelphia, Pa.

CHAMPION, WILLIAM J. JR., Room 103, 19 Congress St., Boston, Mass.

CLARK, LYMAN, General Electric Co., 44 Broad St., New York.

COLLINS, WILLIAM R., Salesman, New York & Ohio Co., 134 W. Jackson Boulevard, Chicago, Ill.

CORDNER, A. R., Meter Tester, Philadelphia Electric Co., Philadelphia, Pa.

CORNOG, THOS. F., JR., Solicitor and Clerk, Beacon Light Co., 515 Market St., Chester, Pa.

DEGEN, G. T., Meter Tester, Philadelphia Elec. Co., 122 Arch St., Philadelphia, Pa.

DONLEY, W. H., Meter Tester, Philadelphia Elec. Co., 317-319 Arch St., Philadelphia, Pa.

DUTTON, LEWIS R., President and Manager, Jenkintown & Cheltenhom Gas Co., Wyncote, Pa.

DUUS, H. G., Meter Tester, Philadelphia Elec. Co., 122 Arch St., Philadelphia, Pa.

FORSYTHE, HENRY J., Solicitor, Philadelphia Elec. Co., Philadelphia, Pa.

GASSNER, GEORGE S., Asst. Meter Tester, Philadelphia Elec. Co., Philadelphia, Pa.

GULLEY, JOS. P., Meter Tester, Philadelphia Electric Co., Philadelphia, Pa.

HAFLEIGH, HORACE M., Manager of Show Room, Phila. Elec. Co., Philadelphia, Pa.

HAINES, E. L., National X-Ray Reflector Co., 247 E. Jackson Boulevard, Chicago, Ill.

HALL, J. MORTON, Salesman and Illuminating Engineer, Nernst Lamp and Cooper Hewitt Companies, 1328 Caudler Bldg., Atlanta, Ga.

Hine, W. C., Treasurer and General Manager, Cleveland Gas & Elec. Fixture Co., Conneaut, Ohio.

Holton, Charles C., Meter Tester, Philadelphia Elec. Co., Philadelphia, Pa.

Hopton, Lemuel R., Superintendent, The Enos Company, 7th Ave. & 16th St., New York City.

Jones, Allen G., Commercial Engineer, General Elec. Co., Schenectady, N. Y.

Kimball, Roger N., Vice-President and General Manager, Kenosha Gas & Electric Co., 210 Wisconsin St., Kenosha, Wis.

Levylier, Henri M., Electric Consulting Engineer, 772 Independencia, Buenos Aires, Argentine Republic, S. A.

Love, E. G., Chemist and Chief Gas Examiner, 122 Bowery, New York.

Loyd, Walter Charles, Post Electrician, Box 733, Highland Park, Ill.

Marsh, George E., Instructor in Electrical Engineering, Armour Institute of Technology, Chicago, Ill.

Meier, Frank B., Assistant Meter Tester, Philadelphia Elec. Company, Philadelphia, Pa.

Morris, Thomas R., General Foreman, Western Avenue Shops, C. M. & St. Paul Railways, Chicago, Ill.

Newman, H. R., Meter Tester, Philadelphia Elec. Co., Philadelphia, Pa.

Pearl, Allen S., Manager, Specialty Department, Central Electric Co., Chicago, Ill.

Rawlings, Thomas, Solicitor, Philadelphia Elec. Co., Philadelphia, Pa.

Riley, H. E., Solicitor, Philadelphia Elec. Co., Philadelphia, Pa.

Schafer, Charles G., Meter Tester, Philadelphia Elec. Co., Philadelphia, Pa.

Schuur, Bernard G., Branch Sales Manager of Company, Cleveland Gas & Electric Fixture Co., Conneaut, Ohio.

Silbert, R. H., Meter Tester, Philadelphia Elec. Co., Philadelphia, Pa.

Simpson, M. V., Salesman, Field Manager, Cleveland Gas & Elec. Fixture Co., Conneaut, Ohio.

Sumley, Wilfrid, Factory Superintendent, Cleveland Gas & Electric Fixture Co., Conneaut, Ohio.

Wilk, W. A., Branch Sales Manager, Cleveland Gas & Elec. Fixture Co., Conneaut, Ohio.

An additional application, satisfactorily endorsed, but not yet submitted for the consideration of the Board of Examiners, was passed upon by the Council for election, subject to the approval of the Examining Board.

The General Secretary was directed by the Council to request the Committee on Certificates of Membership to proceed to

have a final design of the certificate prepared, and to have certificates printed prior to the March meeting of the Council.

The General Secretary was instructed by the Council to send out a second notice to members who have not yet paid their 1908 dues.

PHILADELPHIA SECTION.

At a meeting of the Section held on January 17, Mr. F. N. Morton presented a paper on "The History of Photometric Standards." This paper together with the discussion following its reading, is published in this issue.

The February meeting of the Section was held on Friday the 21st, at which time there were present 59 members and 19 visitors. The Chairman of the Committee on Membership, Mr. J. T. Maxwell, reported that 19 new applications had been filed with the Secretary.

Papers were read by Mr. Robert B. Ely, on "Methods of Illumination with Electric Lamps;" Dr. John T. Krall, on "Eyesight and Artificial Illumination;" and by G. W. Thomson, on "Extension of Gas Illumination." The papers were discussed by Messrs. Furber, Bond, Eglin, Gartley, Israel, Whitaker and Koockogey.

NEW ENGLAND SECTION.

A paper was presented by Mr. L. W. Marsh, on "Daylight Illumination" at a meeting of the Section held February 18. Following the discussion of this paper, Dr. A. E. Kennelly explained a method for obtaining the mean spherical candle-power from a polar diagram by the aid of only a pair of compasses and a protractor, without using a planimeter.

CHICAGO SECTION.

The February meeting of the Section held on Thursday, the 13th, was devoted to the reading and discussing of Dr. Seabrook's paper on "Effects of Light Upon the Eye." This paper is printed elsewhere in this issue.

Chairman Cravath announced the appointment of the following Membership Committee: G. C. Keech (Chairman), C. Howe, E. L. Haines, A. C. Morrison, J. G. Learned, J. Thomas and A. L. Eustice.

NEW YORK SECTION.

On Thursday, February 13, Mr. George Leland Hunter read before the Section a paper entitled "Light and Color in Decoration." The paper was discussed by Messrs. H. F. Huber, E. Y. Porter, A. J. Marshall, Dr. H. H. Seabrook and President Louis Bell. The Secretary announced that at the March meeting Mr. E. L. Elliott will read a paper on "The Relation of Architectural Principles to Illuminating Engineering Practice, from the Viewpoint of an Engineer," and that at the April meeting Dr. E. L. Nichols will present a paper entitled "Daylight and Artificial Light."

Address by Retiring President, Dr. C. H. Sharp, at the Annual Meeting, January 17.

We have now reached the end of the second year of the existence of the Illuminating Engineering Society; and at the request of the Council, the retiring president is following the precedent set last year by Mr. Marks, in reviewing to you briefly certain aspects of the Society's affairs.

The first year of the Society was one of great hopes and of still greater achievement. During that year the Society attained a membership of 815, a phenomenal growth indicative of the great interest which is taken in the subject of illuminating engineering. The past year has not been, as was to be expected, so fruitful in the point of view of increase in membership. During the year 1907, 310 members were elected to the Society, making a total of 1,125 who have been elected. Unfortunately, it has not been possible to retain all of the above as members. During 1907, fifty-eight resignations have been received and accepted, and one hundred and nineteen members have been removed from the roll on account of non-payment of dues. Many of the latter had not, however, fully qualified as members. We must regretfully remember four of our number who have been removed from us by death: Jos. Michael Mahoney, of Boston; J. A. Lewis, of Brooklyn; A. S. Mallory, of New York, and W. J. Phelps, of Detroit, Michigan. I would ask you all to rise in your places, as a mark of respect to their memories. This leaves us with a membership at the present time of 944, a figure which we hope during the coming year to see largely increased.

The most notable event during the past year has been the adoption and inauguration of the new constitution of the Society. The framing of this constitution was accomplished through the devoted labors of a committee appointed for the purpose, whose efforts in its behalf the Society should remember with gratitude. It embodies the results of the experience of older societies, together with a feature which represents a novel and daring departure on the part of an engineering society. Engineering societies in this country are for the most part modelled after the older societies in England, where geographical conditions are very different from those which obtain in this country. In Eng-

land, when an important meeeting of a society is to be held in London, the membership assemble from other English cities for the purpose of attending, the comparatively short distances which are involved making it possible so to do. In this country, the same plan has not operated with as great a degree of success, since the distances of many important centers from New York are so great as to make a monthly journey to this city impracticable. During the first year of our existence we were organized on this plan; with the inauguration of the new constitution, however, we took up a federal form of organization, which marked a radical departure from the older arrangement. During the year 1906, the Society held regular monthly meetings, president over by its President. These meetings were held in the City of New York. Certain branch meetings necessarily did not have the same prestige as the regular Society meetings held in this city. Under the new constitution, this was changed; under it the general Society holds only two meetings a year, one the Annual Convention, which is for the purpose of reading papers, and the other the Annual Meeting, the occasion which brings us together this evening.

The work of the Society during the year is carried on entirely by the Local Sections. These are to a large extent self-governing organizations, which are held together by a common bond, the Council of the Society. During most of the year, the only active body of the Society at large has been the Council and its committees. By it the regular business of the general Society has been transacted. Each Section has its own officers and Board of Managers, to conduct its affairs. Evidently a federal union of this kind, if the bonds of federation are too loose or too weak, is liable to fall apart and to come to destruction. It is necessary in an organization such as ours that there should be a maximum degree of co-operation between the Council and the Sections, and between the Sections themselves. Working at cross-purposes or mutual misunderstandings might easily be fatal. The constitution provides a mechanism, if I may call it such, for keeping the Council and the Sections in close touch with each other. Such mechanism is arranged for by the provision of the constitution according to which the vice-presidents of the Society are equal in number to the number of the Local Sections, and are selected with such a regard for the geographical

location that as far as possible each Section shall have a vice-president of the Society whom it can call its own: thus the vice-presidents are not only officers of the Society at large and members of the Council, but they are also local representatives in the Council of the Sections; and in the Board of Managers of the Sections, of the Council. When stated in this way, the arrangement for keeping the Council in touch with the Sections, and the Sections in touch with the Council, seem to be most admirable. It is, however, my unpleasant duty to say that this arrangement has not in practice, fulfilled the expectations which have been held for it. The same limitations arising from the distances of the cities where local Sections are organized which would prevent the individual membership from attending meetings in New York, have evidently been sufficient to prevent, for the most part, the attendance of the vice-president upon the meetings of the Council.

On this account, the system which the constitution provides has very largely broken down, and there has not been, during the year, the feeling of close contact between the Council and the Sections, and I assume between the Sections and the Council, which is not only desirable, but necessary in order to the success of the Society as it is at present organized. I am tempted to dwell at some length on this point, because the importance of this matter does not seem to have been appreciated as yet by many of those who should be most interested. Without the intimate contact with the affairs and opinions of the Sections which the presence of the vice-presidents at its meetings should secure, the Council is working to a considerable extent in the dark. The Sections have a right to demand of the Council a consideration of their opinions and desires, and the use of its best abilities in administering the affairs of the Society. The Council has, on the other hand, a right to expect such assistance in its work and administration as the Sections are able to give; without this assistance, its actions may well be faulty or unwise.

Under the constitution, the responsibility for such contact and co-operation rests largely with the vice-presidents, who should see that the needs of the Society in this important respect are fully provided for. In case it is not possible for a vice-president to attend each meeting of the Council, he should communicate with the Council in regard to such matters as ought to

be brought to its attention. In this way it is possible for the vice-presidents to keep themselves in touch with the affairs of the Society at large that they are able to present to the Sections which they represent the broader views of the affairs of the Society which the Council must always take.

I think we should turn our attention also for a moment to one other condition which our federal organization as it has operated during the past year, imposes upon us, and that is that the Transactions are dependent upon the activities of the local Sections for the supply of papers, and that the Sections are to a considerable extent mutually dependent upon each other in this regard. How well nearly all of the Sections have met their responsibility in this particular, is evinced by the large amount of most important matter contained in the papers and discussions which the Transactions for the past year contain.

In the foregoing I have endeavored to point out some of the responsibilities and of the dangers which are the necessary accompaniment of an organization which sub-divides the Society into local branches and then leaves to these branches a maximum amount of freedom of action. All of us, I believe, as members of local Sections, are pleased with the liberty which is given to us under the constitution. Do we think of our duties and responsibilities as often as we think of our privileges or of our grievances, if we have any?

Another important event of the past year was the first Annual Convention of the Society. Those who attended this convention were unanimous in the opinion, first that the Society was fortunate in enjoying the hospitality of the Boston Section for that event, and second that the success which attended the Convention, not only on account of its social features, but also on account of the large number and the high order of the papers which were presented to it, was a most excellent augury for the permanent prosperity and usefulness of this Society. There were present on that occasion 202 members and guests, while 19 papers presented there appeared in the Convention Number of the Transactions. It is interesting to note in this connection that the number of papers and topical discussions before all the local Sections during the year was 53.

The work of the year which is past has thus been fruitful in problems to be solved, in responsibilities to be met, and in oppor-

tunities to be grasped. I wish to express my deep sense of indebtedness to my colleagues of the Council and to members of Committees for their loyal and disinterested assistance in connection with the administration of the affairs of the Society; and now that the time has come for me to transfer the office with its duties and its dignities to other hands more capable, I hope, of administering it wisely than I have been, I wish to extend to the incoming officers my heartiest congratulations and best wishes for a harmonious and successful administration.

THE HISTORY OF PHOTOMETRIC STANDARDS.[1]

By F. N. Morton, *Member*.

We have already passed the second centennial in the history of photometry. In 1700, Francois Marie estimated the intensity of light by placing pieces of glass behind each other and then counting the number required to produce total obscuration. The first mention of what we would call a standard, however, was by Bouguer, who, 60 years later, said that the simplest way of specifying the intensity of light was to find out the number of candles necessary to give the same light. He did not specify any particular candle, however. In 1800 the Carcel lamp, the present French standard, was brought out, and from about 1850 to the present time, many different plans were tried, found wanting, and (mostly) abandoned. Although some of the brightest minds in the scientific world have been working on the subject, we must admit that we have not as yet anything which can be called an absolute standard. The candle, which is as near an absolute standard as we have, gives concordant results only through averaging a large number of observations. For scientific work, this is too much like the old English law defining the method of obtaining a legal measure of length, which was to take the first score of men coming out of church, make them stand toe of one to heel of the next in front, and take one-twentieth of the distance from the heel of the last to the toe of the first and call it a foot. There is a ludicrous resemblance which will appeal to those who have had to use candles extensively.

CANDLES.

Tallow. Murdock seems to have been the first to discover that there was any difference in candles, for, in 1808, he specified tallow candles weighing six to the pound and burning at the rate of 175 grains per hour. A few years later, Lord Stanhope proposed that the wicks should be waxed before being coated with tallow.

Wax. The wax candle was used by Ritchie in 1824, and was recommended by W. King, engineer to the Liverpool Gas

[1] Read before the Philadelphia Section, January 17.

Company. In 1849 it was made a legal standard by Parliament which, in that year, included in the Great Central Gas Company's Act, in pursuance of the recommendations of Dr. Leeson and Mr. Cooper, a clause providing that the illuminating power of the gas supplied by that company was to be not less than the light produced by 12 wax candles, six to the pound, each consuming 120 grains of wax per hour. Dr. Letheby, whose duty it was, as chemist to the City of London, to test the quality of the gas, reported that the candles burned irregularly, could not snuff themselves, and that there was difficulty in knowing when they were burning properly. These candles were superseded in England by the sperm candles in 1860 by Act of Parliament.

Stearine. There are two forms of stearine candle, one, the French "bougie de l'etoile," or star candle, and the other the Munich candle.

The former, which attained but limited employment and which went out of use in 1860, was tested by Peclet in 1830, and found to give a light equal to 0.143 carcel. Later tests by Monnier gave 0.136 carcel when five candles came in a package, and 0.131 and 0.132 carcel with a 10 grammes per hour consumption and a flame height of 52.2 mm., respectively, with six candles to the package. According to Monnier, the candle required not only a consumption of 10 grammes per hour, but a flame height of 52.4 mm. The London *Journal of Gas Lighting* in 1859, speaking editorially of this standard, said: "For uniformity and steadiness of light, the stearine candle sold in France under the name of 'Bougie de l'Etoile' far surpasses the ordinary sperm candle." At Melun, the street lighting contract called for a certain illuminating power of the gas in terms of this unit. The municipal tester, to avoid the fluctuations of the candles, applied to the Mayor for permission to use the carcel lamp. In testing to determine the ratio, he found it to be 0.131.

The Munich candle conforms to the type of candle specified in the contract between the city and the gas company, and outside of that place, was never used as far as I am able to learn.

Paraffin. The use of wax candles by Lewis Thompson in a letter to the London *Journal of Gas Lighting,* published in the number of Oct. 11th, 1852. In this letter he says that paraffin is superior to spermaceti and wax, and announces that Messrs. Field are about to commence the manufacture of paraffin candles

possessing a photometrical value equal to 120 grains per hour of the best sperm. He also adds that paraffin has the advantage of being easily tested as to purity, and its composition is easily fixed and determined all the world over, while that of sperm varies with the age and health of the animal, and according to whether it comes from the head or body. There is no record at hand, however, to show that paraffin candles were used to any extent in England.

In Germany, however, the paraffin candle was a recognized standard, being adopted in 1872 upon recommendations of the German Gas Association. The candle had a uniform diameter of 20 mm. and weighed 1-12 kilogramme. The wick was composed of 24 cotton threads, one of which was to be red as a distinguishing mark, and was to weigh, dry, 0.668 grammes to the metre. The paraffin of which it was made, solidified at 55° C.

In the earliest recommendations it was directed that the candle be allowed to burn freely, and when the flame had reached the height of 50 mm., observations were to be taken. Later, however, the recommendation was made that the wick be snuffed to insure reaching the standard height more quickly.

Lummer and Brodhun found great difficulty in seeing the exact termination of the base of the flame, and were also troubled by the top of the flame splitting into three parts, and also by the flame smoking when it was near the normal height. Their measurements show, moreover, that the relation between the flame height and the intensity is not a fixed one, because, at one time, when the flame remained at 50 mm. for some minutes, the readings ran from 0.412 to 0.430.

Sperm. This is the immediate successor in England of the wax candle. It was first used by the Great Central Gas Company in 1852 as a substitute for wax. Two were used instead of one as formerly, and later a long candle was employed, cut in two, and each half burned from the middle to the end. Its general substitution for wax was agitated in 1856, but was not legalized until the Metropolis Gas Act was passed in 1860, which contained a clause specifying the illuminating value of the gas in "sperm candles of six to the pound, each burning 120 grains per hour." Here a wail arose from the gas companies, as the sperm candles gave more light than the old wax in the proportion of 12 to 9½, or of 16 to 14, according to the various authorities.

It was soon found that the sperm candles were very much open to objection, and they hardly came into use before they were made the subject of attack. In 1864, Drs. Letheby and Odling reported wide variations, and similar statements came from Kirkham and Sugg, and others. Capt. Webber and Mr. Rowden at the Paris Exposition of 1867 said that the light emitted was very irregular, even with a uniform consumption; it was affected by drafts, and by manipulating the wick a variation of 10 per cent. in the illuminating power might be obtained even after correcting for variation in the consumption. Even if one experimenter got constant results, his values would not be those of another. Moreover, the intensity was too small, because, for accuracy in reading, the lights to be compared should be as nearly equal as possible. Henry Gore also found a variation of 10 per cent. in candles.

It is needless to quote more opinions in regard to the eccentricities of candles. Every effort was made by the authorities to obtain one that would be reliable, and specifications were extended and multiplied, and rules for manufacture were made more definite, but a satisfactory product was not forthcoming. There is a possibility, however, that the fault lies with the makers to a greater or less extent. It is axiomatic that any standard must be made strictly according to the established rule. At present the specifications are most exact. Dr. E. G. Love, City Gas Examiner of New York, in a spirit of investigation most reprehensible from the manufacturers' view, compared the standard candles received by him with the specifications. This is what he found:—

The specifications called for a wick composed of three strands each of 18 threads. There were three strands, but the number of threads varied all the way from 18 to 24. There should be from 32 to 34 plaits in 4 inches of wick when extended by a pull just enough to straighten it out. The plaits really ran from 27 to 35. The wick, after steeping and drying, should weigh not less than 6 nor more than 6½ grains for each 12 inches. The weight ran from 6.68 to 8.84 grains. The weight of the ash from 10 wicks after treatment with water, should be 0.025 grains. It ran from 0.041 to 0.103 grains. The spermaceti should have a melting point of from 112° to 115° F., and that of the finished material in the candle would be slightly raised by the from 3 to 4.5 per cent. of beeswax added to prevent crystallization. Instead of

this, the melting point was actually between 108.7° and 111.5°. If a 40 grain brass weight is attached to the wick and the candle floated in water at 60°F. taper end down, it should float with a two-grain weight placed on top, and sink with a four-grain weight. And as a matter of fact, some candles sunk without any weight at all, and others did not sink until 12 grains were added.

Not a single requirement was complied with. The candles could not be expected to give uniform results under the circumstances. Mr. Walter Grafton made a very exhaustive set of experiments on the reliability of candles, and laid special emphasis on the necessity of adhering strictly to specifications. His paper, which is really a defense of candles, said that the Referees' instructions should include a diagram of the candle, showing the exact curvature the wick should assume while burning, as this has a marked effect upon the light emitted. As a result of care in manipulation, the average error over the series was 0.002 per cent.

I am not defending the candle. I have passed too many hours with it and been too closely associated with it ever to want to see another. It has been painted in pretty black colors, however, and I believe that it is only fair to give to it whatever commendation there is, for that is little enough.

CARCEL LAMP.

This is the oldest photometrical standard in use today, and was invented by Carcel about 1798 or 1800. It consists (Fig. 1) of an argand burner with a wick and chimney, the oil for consumption being forced by pumps, shown in chamber A, through the central pipe to the burner above. These pumps are operated by clockwork contained in the base. There are three of these pumps, as shown in the small cut, emptying into a common space. An overflow of the surplus oil is always maintained, so that the wick draws its supply from a constant head, insuring uniform conditions. Colza, or rape-seed, oil is used. Dumas and Regnault, who made exhaustive tests of the lamp, found that with a consumption of 42 grammes of oil an hour, there was least variation in illuminating power for a given variation in the oil consumed. The lamp is, therefore, operated to burn that amount of oil, regardless of the height of the flame.

The wick seems to be the delicate part of the lamp. The rules for the official testing of the gas of the city of Paris, and

which were drawn up by Dumas and Regnault, direct that a new wick be used for each test. The wicks should be stored in a dry place, and preferably in the presence of an absorbent of moisture.

In regard to the value of the lamp as a standard, authorities differ. Dumas and Regnault found it satisfactory, while Crova says:—"I do not hesitate to affirm that the French standard is, if not free from all reproach, at least one of the best known; but it must be remembered that photometric determinations are very

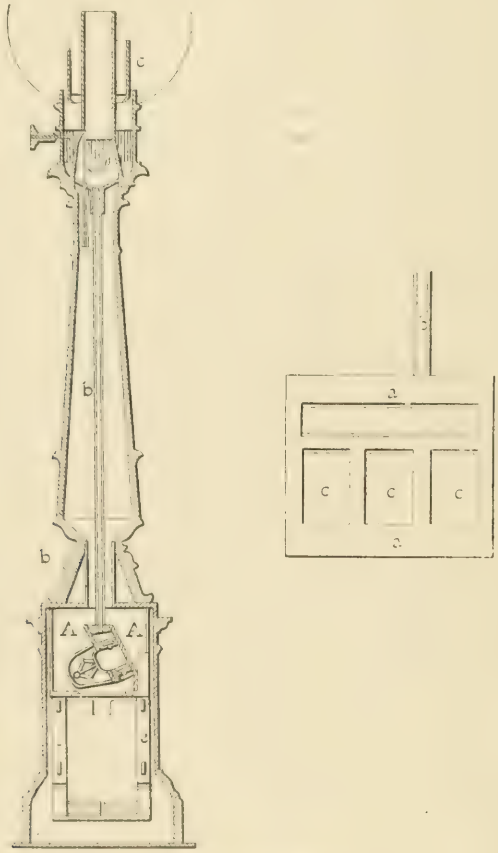


Fig. 1—Carcel Lamp.

delicate and demand a very careful observer. The illustrious Fresnel would not allow anyone else to prepare his Carcel lamp for him. He regulated it, and he himself cut the wick with the greatest care. Under these conditions, it is possible to reach an approximation of 1 in 60, or we may reach that of 1 in 100." He also says that it is true that others, unquestionably expert in photometry, have, through failure to conform rigorously to the rules, found the lamp defective.

Capt. Webber and Mr. Rowden, at the Paris Exhibition in 1867, reported favorably on the lamp, saying that it was but little affected by drafts, that the wick, being entirely below the flame, could not influence the light, and that both the wick and oil were readily tested by the operator. Inasmuch as the wick is actually consumed to such an extent that it is necessary to use a fresh one for each test, there seems to be somewhat of a discrepancy here.

On the other hand, Hartley said that this was a worse standard than the candle; the Dutch Gas Association reported variations in comparative tests as high as 3.89 per cent., and said that it was so inferior that it could not be adopted as a standard, while the Electrical Congress in Paris, in 1881, declared against it.

Peclet, who was one of the first to take up the Carcel as a standard, found a steady increase in illuminating value through four hours of constant burning, amounting at the end of the period, to 17 per cent. After this it remained constant for three hours. Emile Durand says that the lamp should always be tested with a stearine candle before using. Dibdin, in 1888, found a mean deviation of 1.34 per cent., the maximum being 4.1 per cent. In spite of the objections to this lamp, it has remained the accepted standard in France, and is the official standard for testing the gas in Paris.

KEATES SPERM OIL STANDARD.

Keates, consulting chemist for the city of London, objected to the Carcel lamp because the chimney had no fixed position, and a slight difference in placing it affected greatly the light emitted. He also criticised the method of supplying oil to the wick. In 1869, therefore, he brought out a modification of the Carcel lamp (Fig. 2) in which the height of the chimney is fixed, and in which the oil difficulty was overcome by making a row of holes half an inch below the upper edge of the wick holder so that the oil was raised a constant distance by capillarity. The lamp was also modified by having a metallic cone to direct the air against the wick, thus insuring steadiness of flame. It was used in a balance, like candles and the carcel.

Keates said that a worse material than colza oil could not have been proposed. He, therefore, used sperm. The lamp, in its early form gave 10 candles, but later was made to give 16.

In 1881. Dibdin tested the lamp over a period of 6 weeks, reported that 71 per cent. of his observations fell within 1 per cent. of the mean, and all within half a candle. The Board of Trade Committee on Photometric Standards gave it a high rating for steadiness during tests, but rejected it as a standard because of sudden variation in intensity due to failure of the wick.

In 1887, however, Dibdin made another report, in which he said that the lamp could not be relighted without adjustment or renewal of the wick, introducing discrepancies; and, furthermore, various operators found it difficult to obtain flames to uniform character. He said "The lamp has failed in practice . . . .

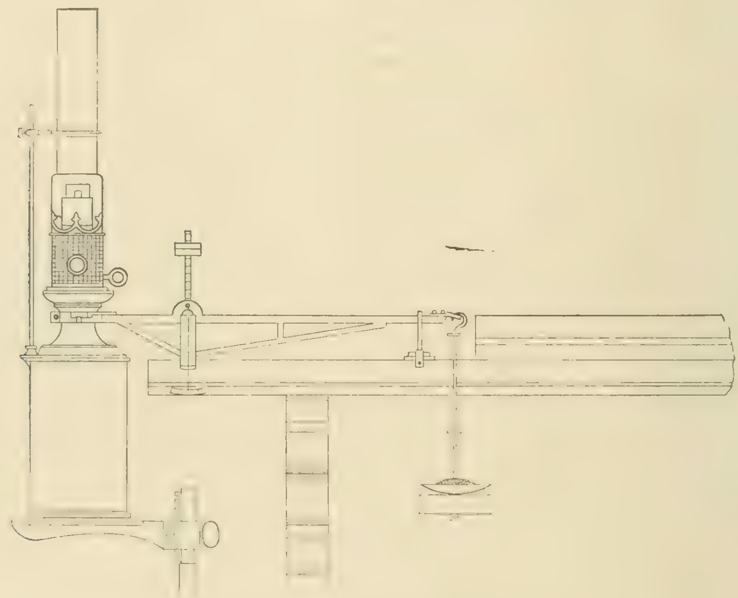


FIG. 2—KEATES' STANDARD.

not so much from any inherent defect as from the severe trial it makes . . . . upon the patience of the observer."

This standard has never passed the laboratory stage.

VIOLLE'S MELTED PLATINUM.

At the Paris Exhibition in 1881, Violle proposed as a standard the radiations of a square centimetre of melted platinum. He then undertook a series of experiments on silver. By means of a thermopile, he measured the radiations through a quartz diaphragm carried in a hollow, water-cooled screen, and found that from the time the edges began to harden, the radiation was very constant. When the centre of the pool began to harden, there was a slight increase, followed by a decrease as the metal solidified. In actual practice, the time of taking the observation

is the moment of solidification of the platinum. This is indicated very exactly by a characteristic flash which is produced regularly and surely when a mass of platinum of not less than one kilogramme is used. One reading having been made, it is necessary to fuse the platinum again for a new observation. It is said that it is necessary to have the platinum absolutely pure, as any foreign material will not only change the melting point, but will cause a scum on the surface of the metal.

One form of the apparatus is shown in Fig. 3. This consists of a lime crucible C, containing the platinum, heated by the oxyhydrogen furnace. When the platinum is melted it is run

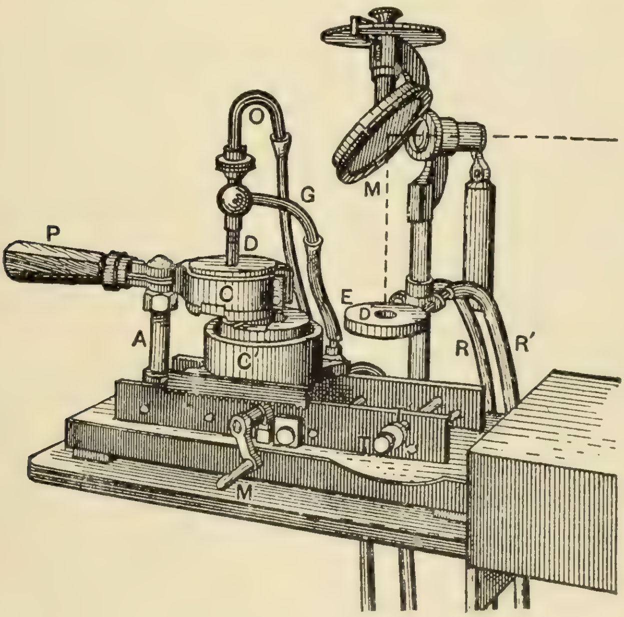


FIG. 3—VIOLLE'S STANDARD.

by the crank M under the water-cooled diaphragm D, the light being reflected to the photometer bar by the mirror M.

Aside from the practical difficulty of using such a standard in everyday work, there seems to have been as much squabbling over this standard as over any other. The system was recommended by a Congress of Electricians held in Paris, and rejected in 1881 by another, while the British Association Committee on Standards of Light in 1888 stated that it was not a practical standard. Dr. Lummer says that where the platinum is melted by blow-pipe flame, it must be rejected as a standard of light, and when by an electric current, there are variations of from 10 to 12 per cent. Von Hefner-Alteneck pointed out that the

temperature of solidification is not a definite point for any liquid, and that the light alters greatly with slight changes of temperature.

In use, the platinum, in quantity of not less than one kilogramme, is put into a lime crucible and brought under the oxyhydrogen furnace. When it is melted, it is run under the perforated, water-cooled, diaphragm by a crank connected with a rack and pinion. The light passing through the aperture is reflected by a mirror to the photometer disk.

This still seems to be accepted as a standard, although its use must of necessity be very limited.

SIEMENS PLATINUM STANDARDS.

To avoid the error in the Violle standard due to variation in the fusion temperature, Siemens proposed to use platinum foil at the melting point. He employed a narrow strip of platinum foil, and heated it to fusion by an electric current; keeping the photometer disk in balance as this point was approached until the light failed. The last setting was taken as the basis for calculating the intensity of the light.

The usual disagreements arose over this standard. Liebenthal obtained very good results with it, finding an average deviation between it and the amyl-acetate lamp to be about 2.9 per cent., while other experiments gave 0.9 per cent. means deviation. Liebenthal says these differences do not result from variations in the molecular structure in the platinum, but from the difference in color, the platinum giving a much whiter light than the other. Lummer and Kurlbaum, on the other hand, found by hundreds of experiments a deviation of 10 per cent. or more from the normal. It must be remembered, nevertheless, that, however accurate this standard may be, it has the serious defects of necessitating catching the observations on the fly, and of admitting only one reading at a time.

REICHSANSTALT HOT PLATINUM.

The Reichsanstalt suggested using as a standard one square cm. of a strip of platinum heated by an electric current to a temperature defined by the ratio between the total radiation and that through a layer of water 2 cm. through, enclosed in a quartz vessel with parallel sides 1 mm. thick. The relative radiations were measured by a bolometer. The strip of platinum is sur-

rounded by a circulating water jacket. The surface of the platinum, which volatilizes in use, becomes as smooth as a mirror, and gives, according to the tests, errors not to exceed 0.5 per cent.

A modification of this method was proposed by J. E. Petavel. He found that radiation through black fluorspar varied inversely as the temperature, while all other substances experimented upon varied directly. The curves of temperature and radiation of black fluorspar and some other substance, glass being selected, must cross at some given point, which was to be the temperature at which to maintain the platinum. The standard, therefore, consisted of a strip of platinum raised to incandescence by an electric current. The platinum strip was placed behind a water-cooled screen containing three openings—the central one pointing to the photometer, and each of the other two towards a thermopile connected in opposition to a galvanometer, screens of glass and black fluorspar of given thickness being interposed respectively. If the radiations are equal, the galvanometer will stand at zero, and the platinum must be at the standard temperature.

Petavel came to the conclusion that only three substances are valuable as radiators: Platinum, platinum-iridium (25% iridium) and iridium.

I have no record of either of these standards appearing outside of the laboratory in which they had their birth.

CROVA'S MELTED ZINC.

As a modification of the melted platinum standard in 1880 Crova suggested using as a standard the light given out by a sq. cm. of the black surface of an iron vessel in which zinc was boiling. Here the constancy of temperature may be maintained, but nothing seems to have come of the suggestion.

ELECTRIC ARC.

In 1892, the adoption of a portion of the electric arc was independently suggested by Jas. Swinburne and Dr. Silvanus P. Thompson. It is stated that if the carbon forming the arc is pure, the light of the crater surface is uniform, except at the edges, which are duller. The temperature, which is as definite as that of boiling water, is taken by Dr. Thompson as 3,500° Cent., and increase of current or voltage, or change in the length

of the arc has no effect on either the temperature or the light emission. Dr. Thompson found, however, that an error might be introduced by the thickness of the diaphragm and its obliquity, and also found that natural graphites always give less light than artificially prepared carbon. The illuminating power of a sq. cm. of hard carbon has been found by Trotter to be somewhat less than 70 candles.

Violle believed that the electric arc formed the seat of a perfectly defined physical phenomenon, the boiling point of carbon being constant. Trotter, who attempted to use it for a standard, found that the effective luminosity is neither consant nor uniform, and the use of rotating sectors showed that the bright spot in the crater seemed to be always revolving. All attempts to prevent this phenomenon, such as enclosing the arc in a small chamber of transparent mica, use of magnets and an air blast, were without effect.

Another attempt to use the electric arc was made by Blondel. who gave to the crater surface an obliquity of from 40° to 60° from the vertical by inclining the carbons. He used a water-cooled screen pierced with openings of different sizes, any one of which might be brought before the arc by rotating. To make sure that the light was coming from the region of maximum brightness, a small lens was dropped temporarily in front of the opening, and an image of the carbon points was projected upon a screen placed at right angles to the photometer bar. Blondel has determined the intrinsic brightness from this source to be 158 candles, the extremes being 150 and 163.

It is of paramount importance for the carbons to be of pure graphite, as any impurity alters very materially the light emission.

ETHER-BENZENE AND ALCOHOL-BENZENE.

Crooke's Standard. Probably the earliest standard of this type was that of Crookes, described in the *American Gas Light Journal* for 1876. He used a lamp whose wick was made up of a certain number of platinum wires of a certain size. The fuel was a mixture of pure alcohol and benzene. The light was claimed to be much more constant than that of the candle. but was too feeble for the lamp to be of practical value.

Blondel's Standard. This also consisted (Fig. 4) of a lamp in which the upper part of the wick tube is surrounded by a

cap pierced with a hole at the top. The flame is surrounded by a chimney, dead black inside, and with two glass covered windows oblique to each other, one to allow the light to pass through, and the other for purposes of adjustment.

Dutch Committee's Standard. The Dutch Committee on Photometry in 1894 proposed the use of a modified Harcourt's one-candle wick pentane lamp as a standard, but with another fuel. Ether alone was found to be too sluggish in passing up the wick; but after mixing with benzene it was found that the variation in light intensity was only 0.1 per cent. for mixtures of from 8.5 to 10.2 parts of benzene to 100 of ether. The mix-

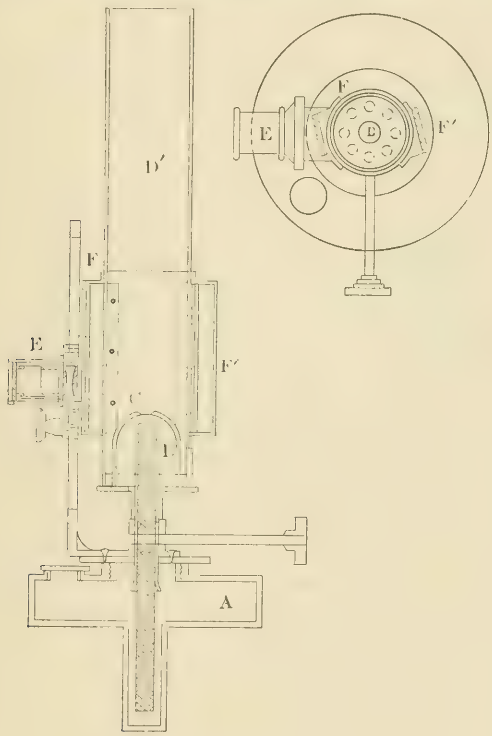


FIG. 4—BLONDEL'S STANDARD.

ture selected was 9 parts of benzene to 100 of ether. Tests showed that the materials did not have to be absolutely pure, and that one did not burn faster than the other.

The lamp closely resembles the one-candle pentane. The upper part consists of a cylindrical metal chimney with two rectangular openings opposite each other. The upper part of the lamp is warmed for half an hour by being placed over a gas jet, after which it is transferred to the reservoir when its warmth at once causes the fluid to evaporate at approximately the required rate, finer adjustments being made by regulating the wick.

The standard is equal to 1.48 English candles. The mean deviation was 2.87 per cent., the extremes being — 9.82 per cent. and — 0.02 per cent. Two lamps compared with each other gave a mean deviation of + 0.62 per cent.

WARTHA'S ETHER STANDARD.

This was brought out in 1874, and consisted of a tank, similar to those used for carbonic acid, placed in a vessel of water. When it was desired to make a test, the water was heated, causing the ether to evaporate, when the vapor, passing through a micrometer cock to a burner of known size, burned with a brilliant white flame.

This is another standard which, never having been used to any extent, never seems to have excited any controversy.

ACETYLENE STANDARDS.

Violle's Standards. About 1895, Violle suggested the use of a perforated screen placed before an acetylene flame, and about a year later brought out a standard consisting of a lamp with a small conical orifice from which the gas issued, drawing in the required air. The whole resembled the ordinary laboratory bunsen burner. The mixing tube ended in a steatite bats-wing burner. Either the whole flame or a part might be used. In the model employed the flame was enclosed in a small box, one side of which was provided with an iris diaphragm, enabling any desired number of candles to be secured, and another side was furnished with a revolving plate containing openings of different sizes, each of which had been carefully calibrated.

Greville's Standard. In 1895 H. Leicester Greville suggested using an argand burner with very fine holes, the height of the flame being adjusted, only a definite portion of the flame being used.

Fessenden's Standard. In a communication to the A. I. E. E. in 1896, Prof. R. A. Fessenden wrote that he had tried to make a slit burner with adjustable edges, with a view to providing a standard. He found, however, that the expansion of the materials with heat introduced appreciable errors. He then tried two small circular jets impinging upon each other at an angle of 90°, which, he claimed, formed an even, luminous flame, only slightly affected by drafts and other atmospheric conditions.

This standard, however, never seems to have been adopted or used by anyone but the inventor.

Fery's Standard. Chas. Fery first suggested using a bit of thermometer tube with a bore of 0.5 mm. as a jet for the acetylene. He found that the luminous intensity was proportional to the flame height between the limits of 1 and 2.5 cm. In 1904 he modified this primitive affair by placing the flame behind a diaphragm pierced with a hole of given size opposite the region of maximum brilliancy. The flame is focussed upon the screen by a lens; and the screen is divided in a scale admitting of exact regulation of the flame. The device also has the advantage of suppressing the penumbra surrounding the cone of rays crossing each other on the diaphragm. A lens in the screen itself projects the rays from the standard to the photometer disk.

In general, the difficulty with acetylene is that it is so rich it has to be diluted with air, and, on account of the explosiveness of the mixture, the orifice has to be so small that accuracy of workmanship cannot be guaranteed. The hole, moreover, is subject to clogging with carbon, altering the proportion of the mixture. Sharp has burned acetylene in a mantle of oxygen, but the flame is so sensitive to pressure changes as to make it unserviceable. Hartman used mixtures of acetylene and hydrogen, and found that the intensity was at a maximum with a half-and-half mixture.

WELSBACH MANTLE.

The Welsbach mantle was suggested as a photometric standard; tests made in this connection at Cornell University showed a rapid fall in luminosity for the first 200 hours, after which the decline was very slow and almost uniform. It was suggested that mantle burners might make satisfactory standards by properly aging, but nothing has as yet been made public to indicate any progress in this direction.

OXIDE OF CALCIUM.

E. L. Nichols measured by means of a thermopile the intensity of radiation from the lime light brought to incandescence by an oxyhydrogen flame, and found a rapid and continued falling off throughout the test. This result confirmed earlier photometric tests. Disks of magnesium oxide and zircon showed

analagous behavior, although there seemed to be reason to believe that the decrease was less rapid than with lime.

ILLUMINATING GAS STANDARDS.

Giroud Combination Standard. While this was not the earliest standard in which the same gas was burned as was to be tested, being brought out in 1882, yet it never came into practical use, and so may be disposed of first.

This consists (Fig. 5) of an open argand gas burner with a glass chimney. Since variations in the flame of this burner can-

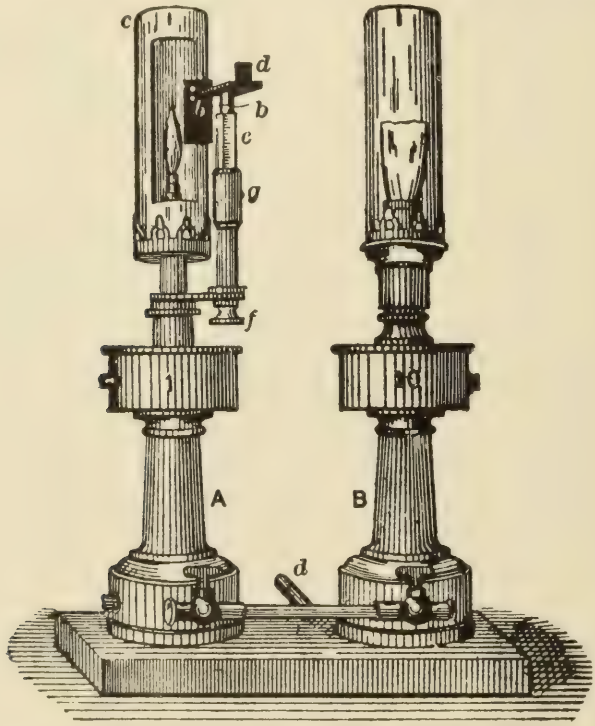


FIG. 5—GIROUD STANDARD.

not be readily discerned in the flame itself, an indicator is provided in the form of a single jet 1 mm. in diameter, and giving a light equal to one-tenth of the other. The height of the indicating jet is gauged by sighting through a perforated screen. An increase in richness of the gas will be accompanied by an increase in the size of the two gas jets (since they are connected to the same source of supply), which is slight in the argand and marked in the jet. The main supply to the two jets is then throttled until the pilot jet is at the standard height, when the argand will be at its normal point.

The standard equals one carcel or ten candles as desired.

Heisch and Hartley made some tests, finding the mean deviation about 2.5 per cent. They think that, in ordinary practice and with a better arranged sight device, the errors should not exceed 3 per cent.

Methven Screen. In 1878 John Methven read a paper before the British Association of Gas Managers, in which he announced that, when gas was burned in similar argand burners at a given height of flame, there was a region in the flame which would, for equal areas, give equal illuminating powers for gases rated at between 15 and 35 candle-power. He had determined the illuminating value of horizontal zones of the flame ¼-in. wide, but found a lack of uniformity due to alterations in the width of the flame, and to variations in brightness at the edges of the flame. He, therefore, adopted as a screen a plate with a hole 1 in. high by ¼ in. in width immediately opposite the brightest portions of the flame, which allowed to pass a light equal to 2 candles.

The report to the Board of Trade Committee on Photometric Standards in 1881, however, while admitting the simplicity and convenience of this standard, reported that its utility was limited to gas which did not vary by more than 2 candles. The report of the Photometric Committee of the German Association of Gas Managers in 1880 was not even as favorable as this, stating that it was more liable to variation than the candle.

On the other hand, F. W. Hartley, who at first was loud in condemnation of the Methven screen, recanted in a paper read before the British Association of Gas Managers in 1880, and said that his own experiments showed close agreement with gases ranging from a rich cannel of 35 candle power to an unenriched gas of 14 candles.

While still expressing faith in this other system, in 1882 Methven suggested carburetting the gas to be used in his standard by passing the gas over trays of very fine gauze through which some hydrocarbon (pentane or gasolene) dropped from one to the other. With this system, he used a 2½-in. flame, instead of a 3-in as before, and also slightly reduced the size of the aperture in the screen. This change abated somewhat the war of criticism and approval waged among the enemies of the standard and those in favor of it. Dibdin, for instance, as a result of a series of tests, said that its inaccuracies must militate seriously

against its adoption with plain gas, but with carburetted gas it was capable of good work. In another report, however, he says that observations by different operators could not be considered satisfactory, as more experience was required with the carburetted gas than would appear necessary. In the same report he found a maximum deviation of 5 per cent. Heisch and Hartley found no difference whatever when gas rated at from 13.65 to 22.4 candles was used, while Rawson and Grafton, on the other hand, said that in over 2,500 tests, the average difference was only 0.31 candles in the gas; and a comparison of 14,600 tests at Beckton with 3,670 made by the examiners showed

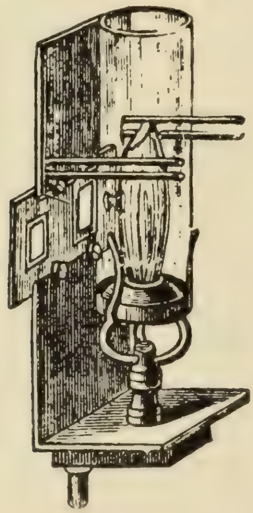


FIG. 6—METHVEN SCREEN.

the candle powers to be 16.52 and 16.58, respectively. He then says that with mixtures of 16 or 17-candle coal-gas and 20 or 21-candle water-gas, there is no serious change until the percentage of water-gas exceeds 14. He also recommends the standard for uniformity, ease of adjustment and general reliability.

In its present form, it consists (Fig. 6) of a Sugg's Argand burner with a flat or concentric screen 1½ in. in front of the centre of the burner. This screen carries a slide in which are two vertical rectangular openings, adjusted to pass a light of 2 candles for the 3-and 2½-in. flame, respectively. The openings are 1x0.233 in. and 0.31x0.585 in., and are cut in silver so that the standard shall not change through corrosion.

This standard has come into very extensive use in England, and has been used more or less in this country, although here the Edgerton has largely covered the field. A modification of this lamp was proposed by W. W. Fiddes who used, instead of a flat screen, a brass chimney with an opening ⅜-in. in diameter opposite the flame. This, according to the author's experiments, gave a constant light of one candle. Nothing was ever done further, however.

Edgerton, or Mobile, Standard. This standard was exhibited by H. H. Edgerton at the meeting of the American Gas Light Association in 1875. It consists of an argand burner with a brass sleeve surrounding the chimney. This sleeve has a narrow horizontal opening extending across it so as to take in the full width of the flame, and a small part of its height. The entire affair is what Methven tried three years later and abandoned in favor of the vertical slot. Since then the back of the sleeve has been cut away to avoid reflecting, and little windows have been provided in its sides to facilitate regulating the flame. The illumination is about 6 candles.

In 1895 Prof. D. S. Jacobus found by experiment that the light centre of the standard was 9/10 in. in front of the geometrical centre, and entirely outside of the flame itself.

Probably owing to the fact that gas men in America, where the Edgerton standard had come into very extensive use, are not so apt to make public their investigations as are their English cousins, not much has been published as to the merits of this standard. Mr. Rollin Norris, however, conducted experiments which showed that with water-gas, it was extremely unreliable, giving variations as high as 4.2 per cent. above and 6.7 per cent. below the average. With coal-gas, he found it somewhat more constant. On the other hand, Mr. A. S. Miller reported to the American Gas Light Association in 1900 that, in a long series of experiments under different conditions, the extreme variation in tests that should be alike was 2.5 per cent., and the tests, in general, seemed to indicate that it is highly satisfactory, provided it is not disturbed after being standardized.

With the Edgerton sleeve, frequent standardizations are necessary, either with candles, pentane, Hefner, or some other form of standard.

Sugg's Ten Candle Standard. This consists (Fig. 7) of an argand gas burner giving a flame regulated to a height of 3 inches. The top of the flame is cut off by a screen which reduces the height of the light to 1¾ inches. The standard is mounted on a meter which registers the amount of gas consumed, and constitutes an indication of the highest value of the variations of the flame.

KEROSENE LAMPS.

Numerous attempts have been made to use kerosene lamps as photometric standards. In 1884, Frederic Egner reported as

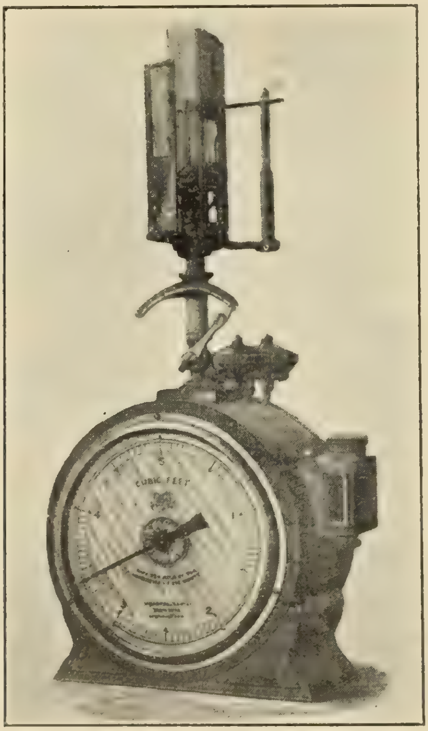


FIG. 7—SUGG'S STANDARD.

the result of some tests, that the light was remarkably uniform. Heim used an oil lamp as a secondary standard with good results. Von Hefner-Alteneck said it was superior to the carcel, and Dr. Clayton H. Sharp used a kerosene lamp with an argand burner, the top of the flame being screened off by a ferro-type iron cylinder fitting close to the chimney. This lamp furnished a very steady source of light, and the intensity was unaffected by slight variations in the height of the flame. Its intensity changed, however, from day to day, and the lamp had to be standardized daily.

Lecomte and Luchaire's Lamp. This lamp, which uses a variety of kerosene known as Stella oil, comprises a reservoir surmounted by a burner using a wick. Surrounding the chimney is a blackened copper box with windows for observing the flame, and an opening partly covered by an adjustable diaphragm to cut down the light to 10 candle power. The lamp is mounted on a balance, and correction is made for consumption of oil in a manner similar to the correction for irregular burning of candles. This is another standard which apparently has never made its appearance outside of the laboratory.

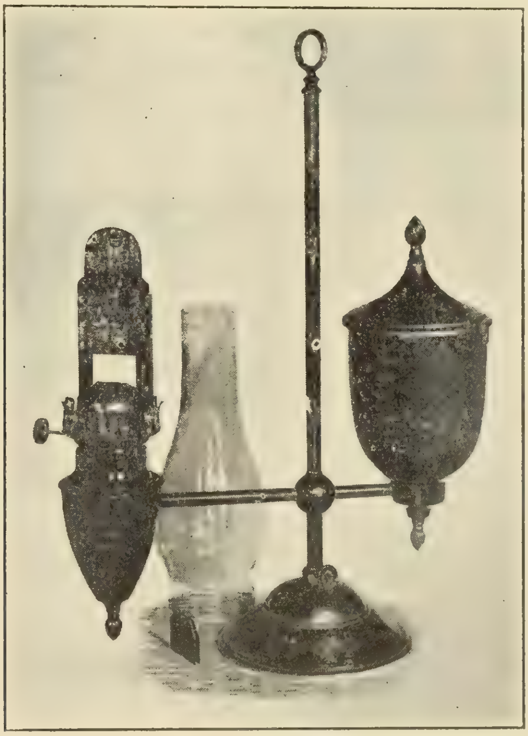


Fig. 8—Elliott Standard.

Elliott Kerosene Lamp. This is of the student lamp form (Fig. 8), with a flat cotton wick 1½ in. wide. To prevent smoky tails, the wick is clipped off slanting at the corners. The chimney is the usual No. 40 Macbeth pearl glass. An adjustable brass screen covering the upper part of the flame is supported upon two upright brass strips riveted to the burner shell.

The inventor claims that his lamp is simpler and more reliable than the pentane lamp, and experiments made by him gave good results. Tests were also made at the Electrical Testing Laboratory in New York, but these are inconclusive as published,

since, while they give the temperature, no mention whatever is made of the other atmospheric conditions. Other tests made at the National Physical Laboratory, London, show a variation of from 10.23 candles to 9.26, the humidity dropping from 13 litres per cu. metre to 11.7. The report states that the experimenters think that the evidence is not sufficient to attribute any change there may have been in candle-power to variation in humidity.

INCANDESCENT ELECTRIC LAMPS.

Incandescent Platinum Wires In 1857 Zoellner experimented with incandescent platinum wires for the purpose of studying the radiations from them, but no reliable results were derived. In 1878, Schwendler revived the plan; but the method was never adopted, owing to variations in the emissive power of the surface of the strip and alterations in its cross-section.

In this connection, although it is not an electric lamp, it might be of interest to mention a scheme suggested in 1866 by W. W. Fiddes. He proposed to heat a loop of platinum wire in the flame of a bunsen burner to which just enough air was admitted to remove the luminosity. He said that the incandescence of the wire immersed in the flame would be invariable for every variety of gas in ordinary use.

Carbon Incandescent Lamp. Many attempts have been made to obtain a primary standard of light from the incandescent electric lamp, but all these failed through lack of constant relation between illuminating power and physical conditions. It has, however, done good work as a secondary standard.

In 1884, Preece used what would now be called an illuminometer in which the standard was 2.5-c. p. Swan electric lamp. The current was regulated until the illuminations were equal, and the candle power was then read.

Photometricians (mostly of the electrical persuasion, however,) seem to agree that in the incandescent electric lamp a satisfactory standard has been found, even if it is only a secondary one. The filament should be in the form of a single loop lying in one plane which is in the axial line of the lamp. The lamp should be aged by running for 50 hours slightly above its normal voltage, and after that, in practice, taking care that the normal voltage is not exceeded. Dr. Fleming recommends before using the lamp as a standard, taking the filament from the origi-

nal bulb and putting it in a larger one, thereby reducing blackening of the bulb. Messrs. Good and Wilde, however, believe that a large bulb is of little value.

Tests made by Clifford C. Paterson showed that there is no doubt that high voltage lamps that will remain constant in candle power for a considerable time can be obtained, but that they cannot as yet be produced with certainty.

A lamp should be standardized at the end of each 20 hours' running.

Osmium Lamp. This is, of course, still to be developed. Revessi found that with constant current, the candle power first increases, reading 103 per cent. of the original after 200 or 250 hours, then slowly decreases to 97.6 per cent. after 800 hours, and 96.6 per cent. after 1,680 hours. At constant voltage, the candle power increases to 106.7 per cent., and then decreases to 98.2 per cent. and 93.2 per cent., the hours corresponding to those in the preceding case. Hence it is better to use constant current with this lamp.

Lamps of this sort, aged and tested are already supplied by the Westminster Testing Laboratory, London.

BOWDITCH'S NAPHTHALENE.

In his book on coal-gas, published in 1867, the Rev. Thos. Bowditch suggests a standard, and shows a touching confidence in it. He says: "If a Government Commission were appointed to examine the whole question of a light measure, I have no doubt that it would adopt the one I now proceed to describe, and would publish such directions as would render error impossible, except to the culpably careless, or the wilfully wrong doing."

The author then says that he would suggest using either pure carbonic oxide or hydrogen, passing it at definite rate through a carburetter containing pure naphthalene, and burning the product. The carburetter containing the napthalene was to be weighed before and after the test to make sure that the proper quantity was consumed.

"The materials used would be invariable, and thus the errors arising from manufacture and personal manipulation would be prevented."

PENTANE STANDARDS.

Simmance's Two-Candle. This consists of twin burners (Fig. 9) each composed of a steatite tube fitted at the top with a brass plug 1 inch in diameter, and through the centre of which a hole ¼ in. in diameter has been drilled. Each burner has a stop cock for regulating the flame. Two blue glass screens are provided with cross wires at a height of 30 mm. from the top of the burners.

The tubes unite at the bottom in one tube which continues down to the base, then along, and then up to the pentane saturator, or carburetter. This is circular, and is fitted with a spiral plate attached to the top of the carburetter, but not to the bottom, thus forming a baffle.

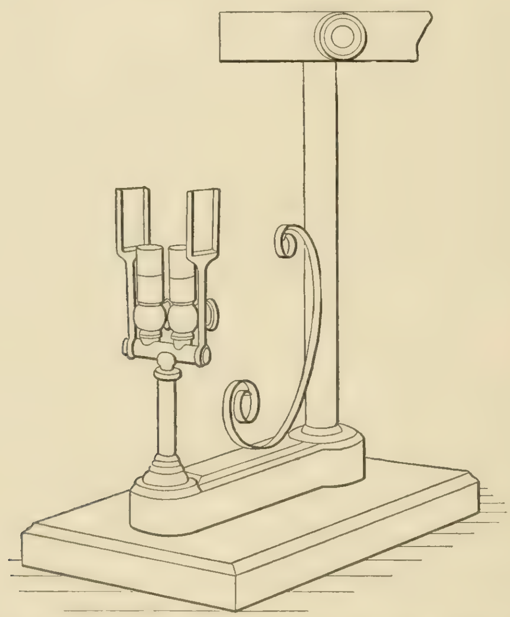


FIG. 9—SIMMANCE'S TWO-CANDLE PENTANE STANDARD.

Sugg's 16-Candle Argand. This was similar to Sugg's 10-candle standard, except that it was not mounted on a meter, the argand was larger, and it was intended for use with pentane air-gas.

Dibdin's 10-Candle Air-Gas Pentane. This consists of a special argand burner (Fig. 10), mounted, together with a pentane reservoir of the bird fountain type, upon a carburetter, consisting of a circular tin-plate vessel with a spiral baffle plate making a passage 4½ ft. for the air to traverse. On the side of the burner to be presented to the photometer disk is a metal

screen $8\frac{1}{2}$ ins. high, and screwed securely to the base plate. The middle portion of this screen is cut away leaving above the top of the steatite ring of the burner an opening 2.15 ins. in height and 1.4 in. in width, the lower portion of the opening being exactly level with the steatite.

This standard was recommended for adoption by the Photometric Standard Committee appointed by the Board of Trade; but, in spite of the influence of the inventor, who was Superintending Gas Examiner to the London County Council, it was never adopted. As a matter of fact, however, this influence was neutralized by that of the inventor of the Harcourt 10-candle pentane lamp, who was on the Board of Gas Referees.

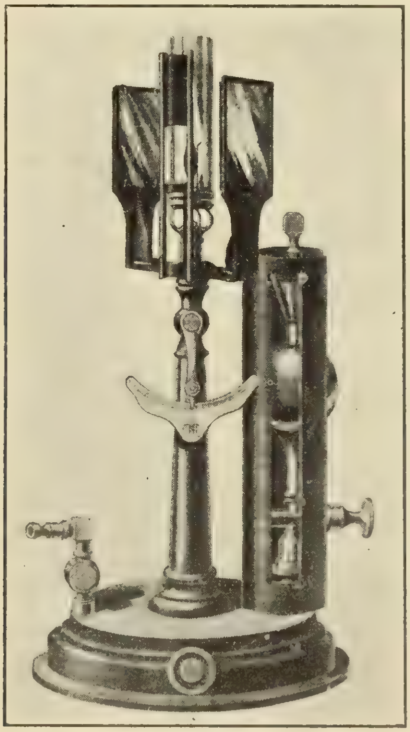


FIG. 10—DIBDIN'S PENTANE STANDARD.

Examinations of this lamp were made by Walter Grafton, who reported that it was nearly half a candle over the 10 candles, and that it was liable to variation from a variety of causes; it was also examined by a Committee of the Institution of Gas Engineers, who confirmed Grafton's report.

Harcourt Hydrogen-Pentane Standard. Probably no other man has devoted anything like the time and study to the solution of the problem of obtaining a satisfactory light standard that A.

Vernon Harcourt has. In 1876 he reported that he had been working on one for two or three years, and had experimented on the use of air and hydrogen for absorbing vapors of "light petroleum" or pentane to make a standard gas. He preferred to use hydrogen, because with air a meter was necessary and corrections had to be made for changes in atmospheric conditions; whereas with petroleum, by acting on an excess of zinc with a known weight of sulphuric acid, an accurately known quantity of hydrogen was obtained without further correction.

In making this gas, Harcourt floated 70 to 100 c. c. of pentane on water in a wash bottle. He then let the hydrogen bubble through the water, evaporating the petroleum and driving the gas into a small holder. He found that a mixture of 1 part by weight of hydrogen and 3.91 of pentane would make a gas of 16 candle-power rating.

Harcourt's Early Air-Pentane Standard. Harcourt seems to have changed his mind in regard to the merits of air and hydrogen for the carrier of the petroleum, because a year later he described an air-pentane standard, making no mention of the first scheme. In this he passed air through a Woulfe's bottle containing light petroleum floating on water, and burned the gas thus made in a burner consisting of a piece of 1-in. brass tube 4 ins. long, the upper end closed by a plug ½-in. thick with a cylindrical hole ¼ in. in diameter. The height of the flame was 2 5/16 ins. and was marked by a platinum wire. The mixture used was 600 volumes of air to 1 of liquid petroleum.

Harcourt's 1-Candle Air-Pentane Standard. Six years after, or in 1883, Harcourt brought out a standard which he described somewhat in modified form in 1887, faintly resembling the present accepted form. It consisted of a reservoir (Fig. 11) of pentane above, feeding by gravity to a burner on a lower level. The pentane is fed drop by drop through a piece of thermometer tubing into a reservoir, or carburetter. The flow of pentane is regulated by a piece of platinum wire inserted to a greater or less extent into the tubing. The air and pentane vapor are drawn from the carburetter through a pipe extending up from the bottom of the vessel, through the liquid and into the mixture above.

The richness of the mixture depends upon the height above the level of the pentane in the carburetter. To adjust this, the bottom of the carburetter is connected with a rubber bag

filled with water, the pressure being regulated by screwing a disk down upon the bag, and thus raising the level of the water and pentane in the carburetter. The bag is represented in the illustration as being in the box to the right, out of which the regulating screw is shown projecting.

To assist evaporation in the carburetter, a copper disk placed above the flame and heated by it, is connected with the carburetter by a copper arm.

In the early form of this lamp, the flame height was gauged by a platinum wire fixed 2½ ins. above the burner, which was

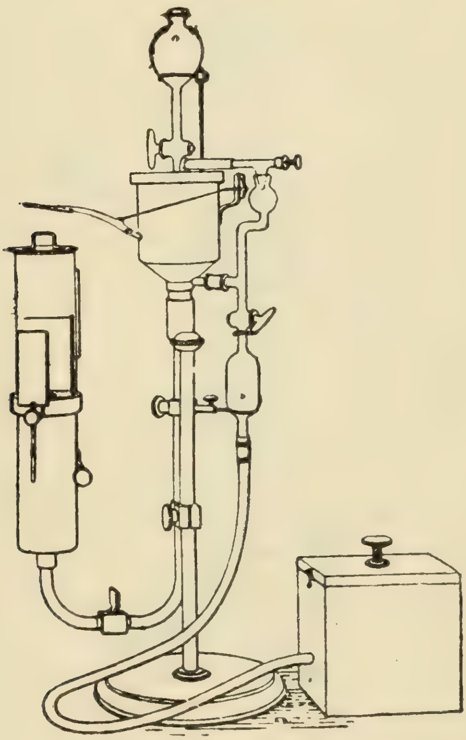


FIG. 11—HARCOURT'S AIR-PENTANE.

the plugged 1-in. pipe before described, and a glass chimney surrounding the burner but not extending above it was used. With the 1887 type, a tubular cut-off was used.

Harcourt's 1-Candle Wick Lamp. This standard consists of a lamp (Fig. 12) with a wick and metal chimney surmounting a vessel, which may conveniently be made of glass. The wick only approaches to within 2 or 3 ins. of the flame, conducting the liquid by capillarity to the tube where it is vaporized by the heat conducted down the tube. The flame is shielded at the top and

bottom by the chimney, the space between which is adjusted to a set of gauges, determining the light.

Tests of this lamp made by Dibdin in 1888 showed a maximum fluctuation of 2½ per cent., while 97 per cent. of the observations fell within 1 per cent. of the mean, and in the same year the Committee of the British Gas Association reported that out of 118 tests, only two showed fluctuations of 1 per cent., which was the maximum. C. H. Clifford, of the Mass. Institution of Technology, and Rawson turned in equally favorable reports. Until the millennium, we shall probably not have any

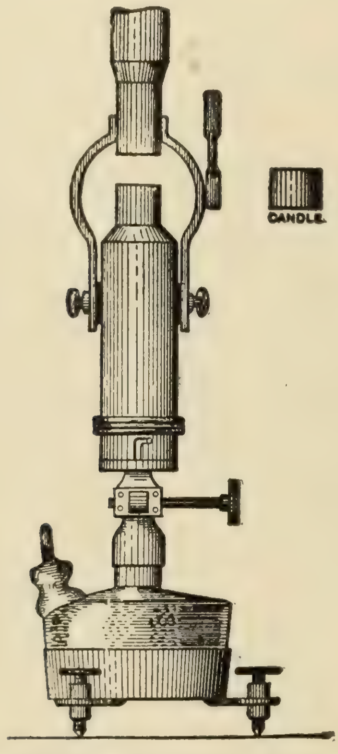


Fig. 12—Pentane One-Candle Lamp.

photometric standard to which some objection cannot be made, and so Walter Grafton, who has been quoted as defending candles and the Methven screen, rises up in criticism of this form of lamp. His experiments show it to be reliable only between 60° and 70° Fahr., and of greater illuminating value than one candle.

Harcourt's 10-*Candle Wick Pentane Standard.* This lamp, which was described in 1894, is the same in principle as the 1-candle lamp, except that it has an argand wick, which does not require cutting nor trimming, as it does not approach the flame. The air admission to the inner tube is through a triangular open-

ing; but to steady the flame, it was found necessary to fix a cylindrical case around the lower part of the tube. The flame is brought to the color of the gas to be tested by admitting a small amount of air below the point of combustion. This is done by drilling a row of small holes through the outer tube 15 mm. from its top. The chimney draft is enough to determine the entry of air through the holes.

A short cylindrical screen surrounds the chimney, the bottom of which is 60 mm. above the surface of the burner; and both the screen and the chimney are surrounded by a pentagonal shade, four panels of which are filled with blue glass, while the fifth, which is turned toward the photometer disk, is filled half way down with a metal plate, which, overlapping the inner screen, allows only the light from the lower part of the flame to fall on the disk of the photometer.

This was Harcourt's last effort before bringing out the present standard which bears his name, and which divides with the Carcel and Hefner, the honor of being the standard of light accepted by scientific, technical and legislative bodies.

Harcourt's 10-*Candle Pentane Standard*. This has become the accepted standard in England; while in America it divides the honors with the Hefner lamp. It was exhibited before the Institution of Gas Engineers in June, 1898, and also before the British Association for the Advancement of Science in September of the same year. In 1898, it was prescribed by the London Gas Referees as the official standard. It is also the accepted standard of the National Physical Laboratory, and is used in the Electrical Testing Laboratory in New York.

The American form of lamp, which is illustrated in Figs. 13 and 14, differs from the English in mechanical details, such as being of more substantial construction. The principal difference, however, is the metal pipe joining the carburetter with the burner, instead of the rubber hose of the English form.

The lamp comprises a rectangular carburetter containing baffle plates, so that the air is forced to make eight trips before it is ready to pass down to the burner, the force necessary being obtained by the weight of the column of air-saturated pentane. The burner is a steatite-ring argand and is surmounted at a height of 47 mm. by a brass chimney. The chimney is surrounded by an annular space which communicates to the burner in such a way that heated air is supplied for combustion. The

flame is regulated by the stop cock at the outlet of the carburetter to a height of 2⅞ ins., the top of the flame being observed through mica windows in the side of the chimney. A conical shield, with an open side towards the bar, protects the flame from drafts. The apparatus is also provided with a spirit level.

The lamp gives a white light of 10 candles, the color of the flame and the luminous intensity making it peculiarly acceptable as a photometrical standard. It has the further advantage of not using a wick with the irregularities incident thereto, not requiring a glass chimney with the possibility of imperfections

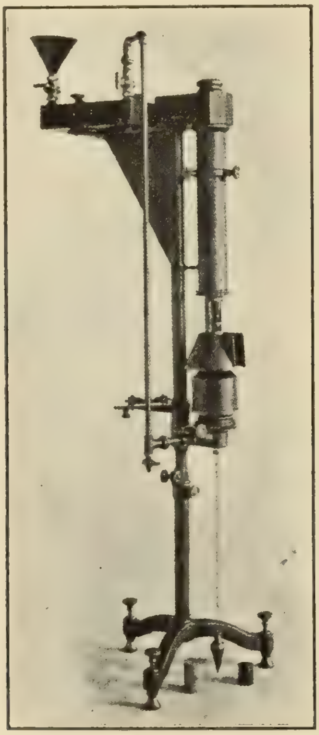


FIG. 13—TEN-CANDLE-POWER PENTANE LAMP.

in the glass and of setting it wrong side around or eccentric, and, since the top of the flame is screened, of being independent of slight fluctuations in the flame height.

Tests were made by Mr. Rollin Norris as Chairman of the Research Committee of the American Gas Light Association, on the possible variations in the luminous intensity of the lamp. The results, reported in the Proceedings for 1900, show that the pentane as commercially supplied, its quality being checked by analysis, exhibits no measurable difference in light giving quality. Where the lamp is in constant use, however, and a large quantity

of pentane has evaoratped, the residue should be occasionally emptied out. A lamp burning continuously for a year, showed no deterioration. A range of temperature from 75° to 100° F. does not affect the light, nor is it seriously affected by a range of 1-¾ in. in barometric pressure. Moisture in the air affects the light, but not enough experiments were made to establish the law.

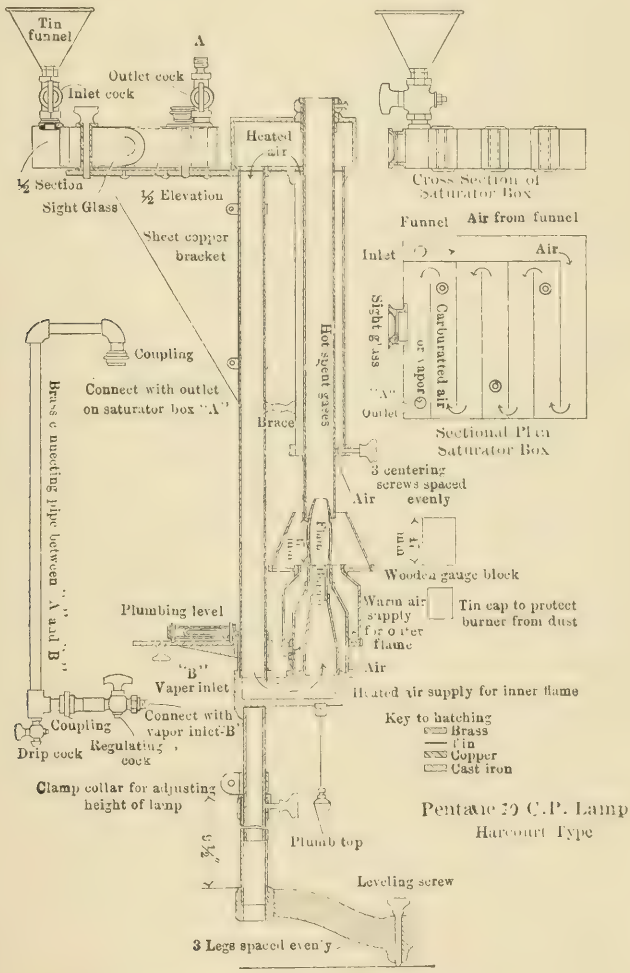


Fig. 14—Sectional View of Pentane Lamp.

I believe that this standard has been subjected to less criticism than any other that has been used or exploited to any extent. As far as I know, Mr. Walter Grafton, who said that its candle power is variable, that it is too greatly affected by temperature, and that the central draft is insufficient, is the only one who really raised any serious objections. Moreover, he read before the (British) Institute of Gas Engineers, a paper in which he concludes that when the parts of the lamp have been ther-

oughly heated and the proper adjustments made, "the standard is worthy of being called by that name, and is as reliable as it is possible to get one."

This leaves the pentane lamp without an opponent—a position held by no other photometrical standard.

HEFNER AMYL-ACETATE LAMP.

This lamp, which was first brought out in 1884, has had great popularity, having been adopted in Germany by the Society of Gas Engineers in 1893, and by the International Electro-Technical Congress at Geneva in 1896. It was recommended as a temporary standard by the committee of the American Institute of Electrical Engineers in 1897, and a brief discussion took place in 1898 before the same association, but no formal action was taken.

It consists of a small lamp (Fig. 15) burning amyl-acetate by means of a wick made of cotton threads, from 15 to 20 in number, laid straight, until the total size of the wick is just enough to fill the wick tube, which is 8mm. in diameter, without squeezing. It seems strange that this is the only requirement for what one would think such a critical point. The wick is raised or lowered by a toothed wheel as in the ordinary kerosene lamp. In the early form of this standard, a glass chimney was sometimes used to steady the flame, but this has been discarded.

The height of the flame, which should be 40 mm., is gauged by a sight device consisting of a short horionztal tube carried on a standard attached to the lamp, and along the axis of which is a horizontal plate. The tip of the flame should be just on a level with the bottom side of this plate as observed by sighting along it. An improved method of adjusting the height of the flame is by the Kruess optical gauge, consisting of a tube similar to the above in the end of which towards the flame is a lens which focuses an image of the flame on a ground glass at the other end of the tube. A line marked on the ground glass admits of easy and perfect adjustment.

There has been much wrangling over the other standards, but I believe that more difference of opinion has taken place over the Hefner lamp than over any other single photometric standard. Some photometricians swear by it, others swear at it. In 1887. Dr. Bunte quoted a number of German authorities, all speaking most favorably of it, and in 1894, Dr. Lummer said that after a

four years' examination, he found that the unit varied not over 4 per cent. as long as the necessary conditions were strictly observed, and allowance made for varying meteorological conditions. On the other hand, Palaz, Dibdin, Vautier, and Dr. J. A. Fleming criticise the lamp, in some respects very severely. The objections to the lamp are: (1) Its small intensity, (2) the red color of the flame, (3) the great changes in illuminating power

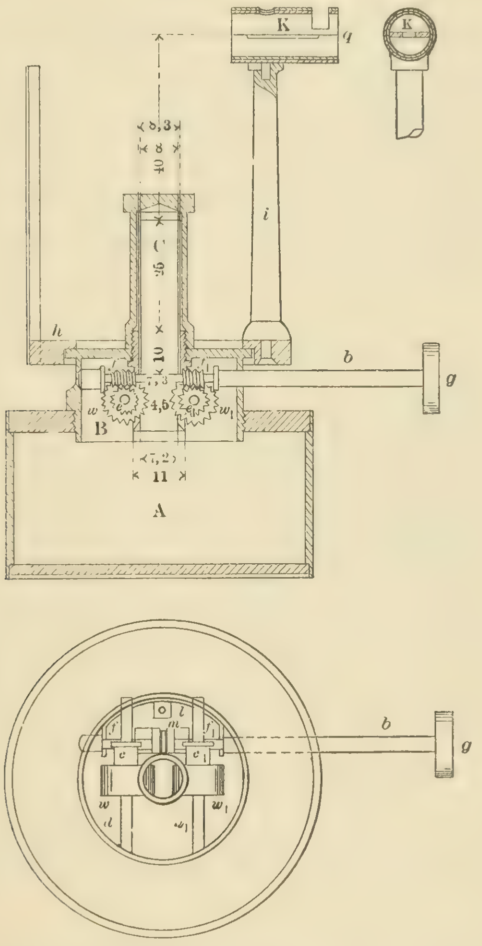


FIG. 15—HEFNER LAMP.

due to slight changes in height, and (4) the extreme flabbiness of the flame which makes it waver and flicker in even the slightest draft and with the least shock or jar.

It has been claimed that this lamp is exactly reproducible, and hence will serve as a primary standard. It is difficult to accept this view, since a test by a special commission of the German Society of Gas Engineers of six standard lamps against the Physico-Technical Institute standard gave values ranging

from 0.965 to 1.016; another test by the same commission found a difference of 2.0 per cent. between the illuminating powers of the two lamps, one constructed by Siemens and the other by Kruess; and finally lamps of Siemens, Kruess and the Physico-Technical Institute gave differences included between + 8.9 per cent. and —3.2 per cent.

The amyl-acetate used is a colorless liquid having the chemical composition, $C_5 H_{11} C_2 H_3 O_2$. It is prepared commercially by distilling amyl-alcohol obtained from fusel oil with a mixture of ethyl alcohol, sulphuric acid and potassium acetate. Liebenthal investigated very thoroughly the influence of impurities and found that, with a flame height of 40 mm., the presence of water and of alcohol as existing in commercial amyl-acetate has no appreciable effect on the luminous intensity, but affects seriously the stability of the flame.

EFFECT OF ATMOSPHERIC CONDITIONS.

It has long been known that moisture, barometric pressure, etc., has an effect on the luminosity of all flames. Harcourt, in 1877, speaks of this, and in 1889, Methven read a paper describing elaborate experiments to determine the effect of atmospheric conditions on candles, and argand and flat-flame burners, as well as upon his own standard. He seems not to have formulated any law, however, nor did the other experimenters, until Liebenthal, in 1895, gave the results of his tests on the Hefner and pentane 1-candle lamp, and deduced formulæ for the effect of moisture and barometric pressure for each.

The latest tests were made by Clifford C. Paterson, the results of which are given. The formulæ deduced are:—

For Moisture:—

Pentane Lamp, $C.\ P. = 10 + 0.066\ (10 - E)$

Hefner Lamp, $C.\ P. = 0.914 + 0.006\ (8.8 - E)$

For barometric pressure:—

Pentane Lamp, $C.\ P. = 10 - 0.008\ (760 - b)$

Hefner Lamp, $C.\ P. = 0.914 - 0.0001\ (760 - b)$, in which E = liters of water vapor per cu. meter of dry air, and b = barometric pressure in mm. of mercury.

Inasmuch as the Carcel lamp was found to vary + 3 per cent from the mean in one day, its constancy is indefinite and no readings were taken.

Paterson did not state the effect of carbonic acid on the Hefner lamp, but Liebenthal found the correction to be in terms of its luminous intensity:

Hefner's = 1.012 — 0.0072 C, where C = liters of carbonic acid in dry and pure air per cu. meter. Multiplying by 0.915, the ratio of the Hefner to the candle, we have,

C. P. = 0.926 — .0066 C.

Paterson made a series of tests on the effect of carbonic acid on the 10-candle pentane. His tests were not numerous enough to draw very definite conclusions, but from the figures he gives I have derived a formula which applies fairly well throughout the range of his experiments. This formula is as follows:—

C. P. = C′ P′ — 0.297 (C — 0.23), in which C′ P′ = candle power corrected for aqueous vapor, and C = liters of carbonic acid per cu. meter, as before.

RELATION OF THE STANDARDS.

There has been as much difference of opinion in regard to the relative values of the standards as to their relative merits. The matter seems to have been settled, however, by the International Photometric Commission at the meeting last year, when the following ratios were adopted:

	Carcel.	Hefner.	Vernon-Harcourt
Carcel	1.00	10.75	0.980
Hefner	0.0930	1.00	0.0915
Vernon-Harcourt	1.020	10.95	1.00

The standards selected for the atmospheric conditions are:—

Barometric pressure, 760 mm.

Humidity:

Carcel	10.0	liters of water vapor per cu. m. of dry air
Hefner	8.8	" " " " " " " "
Vernon-Harcourt	10.0	" " " " " " " "

Discussion of F. N. Morton's Paper by the Philadelphia Section.

Dr. A. H. Elliott:—I want to state that the Elliott lamp was not designed for a standard. I had been bothered by a number of errors with jet photometers, and wanted some kind of a standard —within half a candle or even a candle—that a man could use from hour to hour, so as to regulate the manufacture of gas, especially water-gas, which, varies very much if not properly regulated. This lamp was fairly reliable, although it is not yet a good standard. I found that in lamps with bowl reservoirs, the height of the oil on the wick affected the height of the flame. To overcome that difficulty I use a common lamp, so that the level of the oil is always the same. A round wick with a trailing flame was not very adjustable, so I used a flat wick. The first lamp used was one with a wire gauge with the flame at a certain height, and I was delighted to find that it burned with a variation of only half a candle. Somebody said "If you can cut off a certain portion of that flame and use a certain part of it, you will get better results." So the structure inside was built. This is not one of the later forms. In this latest there is a screen immediately across the cone, so that there is a disk of light 1¾ ins. long and ⅝ in. wide. If two of these lamps are filled with oil out of the same can, and put on a 60-in. bar photometer, in fifteen minutes the lights in the box will be equal. The two lamps can burn for 8 or 9 hours with only about one per cent. variation in candle power. The only trouble with the lamp is that its light cannot be guaranteed at 10 candles. But when standardized, it will give a steady light. Of course, there are certain small points about which one must be careful. For instance, some of the lamps will tail up in the middle a little, then concave the wick a little in trimming. Wicks are cheap and should be thrown away after 6 days' use. Another point about the lamp is to use clean oil.

Mr. C. O. Bond:—This Elliott lamp has been given some trial in the Philadelphia laboratory of the United Gas Improvement Co., and its light was found to be very constant. Experiments were made to find the variation due to water vapor in the

air and it shows up very well. Extreme care was required in trimming the wick in order to preserve a constant flame height. The bar across the bottom of the screen opening which is now used will obviate the difficulty with which we met.

Dr. Clayton H. Sharp:—The paper by Mr. Morton constitutes, as far as I know, the most complete history of standards of light which has ever been written. I myself have devoted considerable time to the study of this subject, and must say that Mr. Morton has brought up some standards of light tonight of which I had never heard. There is no doubt that an enormous amount of effort has been made for the purpose of establishing a reliable standard of light.

The first requirements of a standard of light is that it must be exactly reproducible; that means that it must be reproducible everywhere and anywhere, by means of a description. In other words, we must be able to write a set of specifications by working to which any person properly skilled can reproduce the standard. The intensity of the standard should, if possible, be independent of outside influences. If this cannot be attained, corrections must be made to account for these outside influences, and the method of determining the conditions under which the standard corresponds to its nominal value must be specified. The luminous intensity should be, if possible, entirely independent of the properties of any material. No standard of this kind has been produced as yet.

In practical work we find a necessity for dividing standards into two classes, according as incandescent electric lamps or gas flames are to be photometered. In incandescent lamps we have an illuminant which is independent of atmospheric conditions. the candle power of an incandescent lamp does not vary with the humidity of the air, or with the CO_2 of the air; it does not vary appreciably with the temperature of the air. What we want to compare it with is a standard that does not change with atmospheric conditions. If we have a standard which varies, as all flame standards do, with the humidity of the air, and attempt to photometer an incandescent lamp against it, we will find variations which are due to variation in the standard, unless we reduce all of our standard readings to atmospheric conditions. Hence arises the necessity for secondary standards in the form of incandescent lamps. Seasoned incandescent lamps furnish

us a means for maintaining an invariable even though not a definable unit of light. In reading the candle power of gas on the photometer, since as we know that the candle power of the gas will vary with the atmospheric conditions, it is desirable to measure it against a standard which itself varies with the atmospheric conditions. and, as nearly as possible to the same degree as the gas itself. The requirements, then, are different in this respect from those of the incandescent lamps.

As we have seen, all the practical standards of the present time are flame standards. In a flame standard we should have a definite burning material, one preferably of definite chemical composition, and combustion should take place under a definite set of conditions.

Both of these requirements have been aimed at in the specification for the old British candle, but they have been very imperfectly attained. The candle has a burning material which has no sufficiently definite composition. In a sperm candle, it depends upon the whale, and upon the mixture of beeswax which the maker of the candle has seen fit to add to the spermaceti. The conditions of burning have also not been adhered to strictly since, as we have seen in Dr. Love's tests, the wicks of the candles vary. Moreover, no account has been taken of the atmospheric conditions and their effect upon the luminosity of the candle.

In the 10-candle pentane lamp, which must be taken very seriously at the present day, the first requirement has also been to a considerable extent disregarded. The pentane, as burned in this lamp, is not a definite chemical compound. It is a mixture of pentane with lighter hydro-carbons. When it is prepared according to the specifications of the Gas Referees, the value obtained is practically constant, but it nevertheless lacks the advantage of being a definite chemical compound.

The Hefner lamp, which is the great competitor of the pentane lamp, uses a burning material which is of definite chemical composition, which can be obtained in a chemically pure state from reputable chemical manufacturers.

Now, another point: Reproducibility of the standard depends—both in the case of the Harcourt lamp and of the Hefner lamp—upon the mechanical construction of the lamp; upon the accuracy with which the lamp is made. In all mechanical work it is necessary to allow a certain amount of tolerance and variations in dimensions, consequently it is of importance that the

mechanical dimensions of the lamp should have the slightest possible influence upon the intensity of the light which it gives out, and also that those dimensions which are of vital importance in determining the value of the standard should not only be accurately laid down, but should be accurately reproducible. It is important that as few parts as possible of the lamp should have to be made with a high degree of accuracy, and hence it should be as simple in its construction as possible.

If we compare the Hefner lamp—a lamp with very few parts—and the 10-candle pentane lamp with a good many parts, at first sight the comparison is in favor of the Hefner lamp. The vital dimensions are the diameter, the height and the thickness of the wall of the wick tube, and also the distance between the top of the wick tube and the line which is marked by the drawing across the ground glass. It should not be difficult to make the wick tube of a definite height and definite thickness. It is easy to determine with the gauge that goes with the lamp whether the condition of the height of the wick tube is correct, and whether the flame gauge has been accurately adjusted. Having determined the accuracy of these dimensions there is obtained a lamp which burning with this material of definite chemical composition, with a flame of the height indicated by the gauge, gives a certain quantity of light under certain atmospheric conditions. The Hefner lamp then is the flame standard reduced nearly to its lowest terms.

In the pentane lamp the construction is much more complicated, and its specifications are much more difficult to carry out. As a reproducible primary standard of light the Hefner lamp has a great advantage over the pentane lamp. The disadvantage is that it gives only nine-tenths of a candle, while the other one gives 10 candles. Moreover, it is affected by any draughts of air so that the adjustment of its flame height is difficult. The pentane lamp is not subject to variation from such slight causes.

There is another important point in which all of these standards are defective, and that is color. The Hefner gives a light which is perhaps redder in color than any of the other commercial sources of light. The pentane lamp is somewhat better. At the present time metallic-filament lamps are coming into use, which are whiter still, and they are drawing further and further away from the standard. We have the Welsbach burner which

gives a color which can hardly be compared to that of the Hefner at all. The electric arc is altogether beyond the range of accurate photometrical observations on account of its color.

We should seek for a standard of light which is not only reproducible but which has a definite color value, somewhere near the centre of gravity of color values of practical illuminants, thus it would be far whiter than any of these standards of today. A color like that of the tungsten or of the acetylene flame is about what is required.

It is unfortunate that no one has had the time and the patience to devote to the completion of the work of producing a satisfactory standard of light using acetylene gas. I think it could be done. However, modern researches in the direction of radiation make it seem that the possibility exists of getting a standard of light which will not depend upon the proportion of any substance, but which can be defined in terms of watts of radiant power; which will have any color value which may be determined upon, and which will not be beyond the experimental range of the great national laboratories. Having obtained a primary standard of this kind to be maintained by these laboratories, there will be no difficulty in getting secondary standards of light.

At the present time the photometry of incandescent lamps in this country, which constitutes almost an industry by itself, is carried on entirely by secondary standards in the shape of incandescent lamps. Pentane lamps and candles, etc., are not used at all. By holding fast to a unit which has been fixed once for all, and by continually copying the primary or original standards and sub-standards, the practice in incandescent lamp photometry has cut loose from the primary standards entirely, using instead a secondary standard which has the great advantage of being invariable.

The conditions in the gas industry I believe are not so favorable, but that is a point on which others may talk tonight who are more capable of speaking on that subject than myself.

Mr. C. O. Bond:—The metal base of the Hefner is quite wide, say three inches across, and vertical air currents are affected there. If the Hefner lamp were designed with a different base, so that the field below was left as free as it is in the candle, would it not result in a more rigid flame?

Dr. Sharp:—Dr. Liebenthal states that the flame of the Hefner lamp is made steadier by using a wick-tube with a thicker wall, and gives it as his opinion that the lamp ought to be changed so as to increase the thickness of the wall of the wick-tube, which I think increases the amount of heat conducted down to the wick and raises the temperature of the vapor before it gets to the flame, so that it goes out with more velocity. I have always had the opinion that the unsteadiness of the flame is due to the specific gravity of the vapor.

Mr. W. H. Gartley:—The Hefner lamp has been tested by and bears a certificate from the Reichsanstalt, which is the National German Physical Laboratory. The carcel has passed their inspection. The Carcel lamp has also been passed upon by the Laboratoire Centrale in Paris and a certificate given. The pentane lamp has been compared with a lamp from England. Thus they are the true representatives of the different countries.

The Hefner lamp is advantageous in being portable. From reliable information on record the light from candles varies 10 per cent. from the average under normal humidity conditions and 15 per cent. in the varying humidity conditions which are common to Philadelphia. The candles vary in light very much more under given changes of humidity than the Elliott lamp does. Consequently it would be better if the lamp were standardized by comparison with some other primary standard which has the same or about the same effect under all humidity conditions. There are now three accepted primary standards of light; not units, but primary standards. Their adherents all claim that they are reproducible. An enormous amount of work has been done by investigators to come to an agreement upon the relative value of the light, and I am glad to say that there is now only a small margin of disagreement.

Chairman Bond:—Dr. Sharp spoke of the tendency to substitute the metallic filament lamp, or the tungsten and tantalum filaments for the old carbon filament, yet in the Bureau of Standards at Washington, and other places, the value of the unit is maintained by means of the carbon filament. Is there a chance that the carbon lamps will not be manufactured in the future, or will it be manufactured solely for the purpose of preserving the unit?

Dr. Sharp:—I think it will be a long time before the carbon lamp becomes entirely a back number. The metallic-filament lamps are pretty sure to displace it to a certain extent, especially in the high candle power lamps. We do not know just what we shall have to do in the photometry of a white light like that of the tungsten against a yellow light like that of the carbon. Used as standards, carbon lamps are burned below their normal temperature, hence their light is redder than normal, and thus the existing difference between the color of the carbon and the tungsten is exaggerated. The characteristics of the tungsten lamp, as shown by its life tests, seem to indicate that it will be more valuable as a secondary standard than the carbon lamp has been. It shows less tendency to decrease in candle power with time, and I rather think we shall have to come to it as our best secondary standard. At any rate, the advent of the tungsten lamp seems to demand the maintaining of an entirely new line of sub-standards in tungsten filaments, against which to photometer tungsten lamps commercially. We shall then have carbon lamp sub-standards, and tungsten lamp sub-standards, which are of the same candle power as established once for all by measurements made by a large number of observers, each series to be used for its own particular class of work. In this way photometric difficulties due to physiological causes may be avoided. The white light of the tungsten lamp makes it valuable for standard purposes, because it comes near the average of the primary sources of light at the present time. As a means of maintaining a constant source of light, the tungsten lamp is invaluable.

Mr. T. J. Litle, Jr.—Mr. Morton mentioned that the Welsbach mantle had to some slight extent been considered in the way of a standard. The gas men do not consider it a standard, but we do use it as a secondary standard when photometering large units, such as gas arc lamps, where it is difficult to use a small standard, in which case we use a carefully sponged mantle which has been burned a long period. By disposing of a large volume of gas in a gasometer, and by regulating that gas and feeding it to a secondary standard, first determining the photometric value of the secondary standard, we then run through tests until we find the color of the standard is the same as that of the light to be measured.

TOPICAL DISCUSSION ON RESIDENCE LIGHTING AT CHICAGO, JAN. 17, 1908.

INTRODUCTION BY MR. GEO. H. JONES ON "THE HOUSE ELECTRICAL," AT THE CHICAGO ELECTRICAL SHOW.

The many recent improvements in electrical appliances; the introduction of high efficiency lamps, and the great reduction in the cost of electricity are combining to put the "House Electrical" within the reach of thousands who, only a short time ago, regarded the use of electricity a luxury to be indulged in only by the few.

In order to plan properly the electrical installation for a residence, familiarity with complicated curves showing methods of determining candle-feet, etc., is not necessary, but good judgment and a thorough knowledge of the requirements must be brought into play in order to insure satisfactory results. The treatment of this subject may be divided into two parts, namely, the planning of outlets and fixtures to be used strictly for illumination, and the placing of outlets for use of the many household appliances, such as heaters, motors, etc.

In laying out the scheme of illumination two general considerations should be borne in mind, namely, the every-day requirements and special requirements, such as the illumination required for parties, etc. For the every-day needs an economical arrangement of lamps is necessary. The general illumination should not be intense, but by the use of portable lamps strong illumination may be secured at points where it is needed. Sufficient candle-power, however, must be provided to give brilliant illumination when the house is open for the entertainment of guests.

Much care and judgment should be used in the selection of fixtures. The present tendency is to place the lamps high up near the ceiling. This is made almost a necessity if the new tungsten lamps are to be used. As they are made only in the larger sizes, they should be placed out of the ordinary line of vision.

In rooms provided with a number of lamps strong concentration reflectors should not be installed for general illumination.

During a large part of the time probably only one of the lamps will be in use, with the result that one spot in the room will be brilliantly illuminated to the detriment of the rest.

One of the many advantages of electricity is the ease with which it may be controlled. It is very desirable therefore to have the house equipped with a liberal supply of switches. For ceiling outlets of five or more lamps it is desirable to provide two switches so that either one lamp or all may be lighted. Where rooms have two points of entrance at a considerable distance apart the ceiling outlet should be controlled by two three-way switches—one at each entrance. Three-way switches should also be provided to control the hall and stairway lamps. In the parlor and living rooms where desired, outlets should be provided for picture lighting. Each outlet should be placed behind the picture and controlled by a wall switch.

Every closet should be equipped with a lamp. There should be either a pull wall socket placed on the inside of the door casing or else a ceiling outlet controlled by a wall switch. Automatic door switches are convenient, but they should be used in series with a standard switch, so that the lamp may not be in use when the door is left open for airing the closet.

Practically all of the living rooms of the house should be provided with baseboard outlets for the use of portable lamps, fans, etc. Of course these appliances can be connected to the chandeliers and brackets, but when baseboard outlets are installed the cords are not so much in evidence.

At the present time most of the lighting companies offer motor rates for electricity used in heaters, etc. It is very desirable, therefore, to install a separate meter and circuits which can take care of this class of work so that advantage may be taken of the lower rate.

In the "House Electrical" exhibited in the Coliseum the Commonwealth-Edison Company has endeavored to bring out the general principles outlined in the above and also to show in actual operation many of the household appliances now on the market.

In the entrance hallway the necessary illumination is furnished from a center ceiling fixture and a newel post fixture, each being equipped with 50-watt Gem lamps. An electric foot warmer and a silk-hat iron are installed. The center lamp is controlled by two three-way switches, one located on the side

wall and other on the stair landing. This room is also equipped with a telephone.

In the living room there are two ceiling fixtures each equipped with one 40-c.p. Gem lamp and eight round 16-c.p. frosted lamps. Each of these fixtures is controlled by two wall switches so that either the center or outside, or all lamps, may be used at will. For additional general illumination four two-lamp brackets equipped with 20-c.p. Gem lamps are provided. In addition to the above a portable stand lamp for reading is provided, this being furnished with four 8-c.p. lamps. Several wall receptacles are installed for supplying electricity for a piano, etc. Another feature of this room is an electric grate which provides heat without ashes or dirt.

Especial attention may be given to the fixture provided for picture lighting in this room. The lamp is long and tubular of small diameter with a single filament extending from end to end, thus allowing the fixture to be made very small, which is desirable. The outlet connected to this fixture is controlled by a wall switch.

In the dining room there is a center chandelier equipped with six 8-c.p. round frosted lamps and one 40-c.p. Gem lamp. The lamps are controlled in groups by wall switches placed near both doors. In addition to this are two three-lamp brackets equipped with 8-c.p. frosted candelabra base lamps. In this room there are also a coffee percolator, electric chafing dish, and an electric tea kettle.

The butler's pantry is equipped with a 40-c.p. Gem lamp in the ceiling and a 20-c.p. bracket lamp. In this room there is a refrigerating machine, making the "House Electrical" entirely independent of the ice crop; there are also in this room an electric plate warmer, electric toaster, electric hot water heater and an electric humidor.

The modern kitchen lends itself very readily to the use of electricity and much ingenuity has been exercised in developing many useful appliances to be used in it. Special attention should always be given to the lighting of kitchens. In the kitchen of the "House Electrical" there is one ceiling lamp for general illumination and four bracket lamps over the various work tables, so that strong light may be had where it is most needed. The appliances provided in this room consist of an electric dish washer, an electric range including the necessary utensils,

broilers, griddles, stoves, etc., electric oven, coffee grinder, waffle iron, polishing machine, meat grinder, ice cream freezer, etc.

The laundry is equipped with a 40-c.p. lamp in the center and two 20-c.p. lamps in wall brackets. The other equipment consists of electric washing machine with tub and wringer, electric flat irons, electric hot and cold mangles, and a portable vacuum cleaning outfit.

In the nursery and sewing room the necessary illumination is obtained by means of one three-lamp outlet equipped with 20-c.p. lamps and two two-lamp bracket outlets equipped with 2 Hylo lamps and two 20-c.p. Gem lamps. In this room will be found one of the greatest conveniences of the day; that is, the electric sewing machine. Other appliances to be found in this room are small hot water heater, a nursery milk warmer and also a number of electrical toys.

The bed room is illuminated by one 40-c.p. ceiling lamp, eight brackets with eight 20-c.p. lamps, one 8-c.p. bed room lamp and a portable fitted with a 20-c.p. lamp. Special attention may be given to the brackets in this room. They are so equipped with attachments that appliances may be readily connected. In order to accomplish this a Hubbell receptacle is placed on the under side of the bracket. An appropriate dresser lamp is provided so as to throw the light exactly where needed. This fixture consists of a pendant equipped with pull socket. The bed room is equipped with an electric heating pad, curling iron, hair dryer, etc.

Some of the special features in the bath room are the adjustable fixtures on either side of the mirror so that shaving may be done with comfort. The outlets connected to these lamps are equipped with flush receptacles to which may be attached small heaters, electric shaving mug, hair dryers, vibrators, or any number of other useful contrivances. Baseboard outlets are provided for the use of electric radiators on cold mornings.

In the "House Electrical" there is shown only the application of electricity for interior use. In planning the installation for an actual house one should not forget to provide porch lamps and also arrange to light up the driveway and barn. Another point which might be mentioned is that of branch wires. In cases where houses are set back a considerable distance from

the street and where the pole line is in the street, it is very desirable to place the wires underground from the house to the nearest pole, as wires crossing a lawn overhead should be dispensed with if possible.

DISCUSSION.

Mr. Albert Scheible:—Being planned for exhibition purposes, it is natural that the lighting fixtures in this suite of rooms should be rather more elaborate than they would be in the average house. Now, could any one here, perhaps best of all Mr. Jones, who is so deeply interested in the arranging of the wiring for houses on the installment payment plan for the Commonwealth Edison Company, tell us just to what extent he would modify them to suit the average purse?

Mr. Geo. H. Jones:—I might say that the candle-power of the lamps used in this house is higher than would actually be required in the average residence, because of the surroundings in this building. As the general illumination of the Coliseum is so very intense a degree of illumination in this house on exhibition which would be satisfactory in actual practice would look very dim in comparison. The general plan of lighting, however, is the same as I would use in any first-class residence.

Mr. E. W. Lloyd:—The fixtures are very much more expensive than would be used for ordinary installation. A very acceptable ceiling lamp can be obtained for 25 per cent. of what those cost, and a layman wouldn't know the difference.

Mr. W. R. Bonham:—I am somewhat disappointed in the "House Electrical." I expected to see something a little different from the ordinary. It seems to me we have here the ordinary method of lighting, that is, we have a great amount of light obtained in the ordinary way. I hoped to see something new in the way of efficient and effective lighting, something novel, something outside of using a great amount of electrical energy.

Mr. Geo. C. Keech (chairman):—There is one very important point to take into consideration, which is the fact that there is such a great number of outlets, and it is not necessary to have all the lamps lighted at once. In the bed room, for instance,

one lamp could be used where needed instead of a great number. A single lamp could be used locally, here and there. No doubt many of the outlets were put in to show what can be accomplished in local illumination.

Mr. J. R. Cravath:—Possibly it was rather unfortunate for us to take this house as an example of the lighting of small houses and apartments, in view of the fact that this house must necessarily be a kind of a show affair. The Commonwealth Edison Company evidently thought, and probably rightly, that it was called upon to show something a little extra in the line of fixtures rather than something that would be put in the ordinary home of a citizen of moderate means. There are, however, a number of points in connection with the illuminating engineering of the house that it seems to me could be considerably improved upon. Illuminating engineering, as it is to-day, is largely a matter of first getting the essentials right and next watching the details. About the only criticisms I have on the house, as it stands, are on details. Beginning with the bath room; there is an adjustable fixture on each side of the mirror by which one can lower or raise the lamp so the light will shine under the chin of a man who wants to shave or on the top of the head of the woman who wants to see whether her hair is properly arranged. The fixture is excellent. However, there is a piece of glassware there which nine times out of ten in practice will be found out of adjustment. It is a shallow half shell shade. Frequently such a shade will be found accidentally turned in the holder so that the light shines in a person's eyes. The fixture should be equipped with some kind of diffusing globe covering the whole lamp. In the bed room there are two table lamps which remind one of the kerosene lamp age; of the days when there were unshaded kerosene lamps standing around promiscuously on tables with undiffused light shining in one's eyes. It seems to me that the arrangement should not be commended. Dense opal on art glass or silk should be used on table lamps. As far as I can learn, there is no reflector over the lamps in any of the ceiling bowl fixtures, and consequently there must be considerable loss. They could easily be equipped with an opal or some kind of opaque reflector that would reflect the light down where needed and waste less in the upper part of the room. In the bed room, the lady's dressing table which has a bracket on each side about 5.5 ft. high

(a proper height for a person standing), should have the brackets considerably lower for a person sitting. In the laundry and also in the kitchen the side brackets over the tables (about 5.5 ft. high) are very low. The result is the lamp is on a level with the eye of the worker. The Holophane reflectors used do not shade the lamps sufficiently. A dense opal or an entirely opaque reflector should be used there. The Holophane bowl reflector in the centre of the ceiling kitchen is well chosen. There is an even distribution of light over most of the kitchen, and the same is true in the laundry. The dining room with its ring of six lamps over the table requires more electrical energy than would be permissible in a small house.

Mr. G. A. Stickney:—The points which have been brought out so far have to do very largely with the competition between the demands of economy on one side and the demands of beauty on the other. Of course, it is necessary to maintain a house within an expense which the owner can afford. On the other hand, it is to be remembered that the house is a home in which particularly the lady members of the family are compelled to spend a large portion of their time. The home should, therefore, be made as beautiful and attractive as possible. I presume the Commonwealth Edison Company had this in mind in designing the "Model House." From a very casual observation it seems to me that the designers have been successful in producing a beautiful result In applying illuminating engineering to house lighting, the production of pleasing effects is usually more important than obtaining maximum intensity of illumination or maximum economy. Take, for instance, the lighting of a living room from lamps on the ceiling or the side walls. The ceiling lighting, we all know, is more economical for the production of general illumination. The side lighting, however, is often more suitable in producing a pleasant effect. Another instance where the effect is important is in the lighting of the dining room table; a strong central high lamp should be avoided. With such a lamp the shadows tend to emphasize the lines of the face, making the diners appear tired. The result counteracts the good cheer which should go with a dinner.

An example of misapplied illuminating engineering came to my attention some time ago. An illuminating engineer planned the lighting of a house for a wealthy lady, specifying a light-

ing system which was undoubtedly economical as far as the production of an even illumination of high intensity for a moderate cost was concerned. The engineer had, however, ignored the aesthetic effects. The client objected to the plans, and when they had been modified to conform with the effects desired the economical illuminating engineering had practically been lost. This instance illustrates a tendency to which an engineer is sometimes liable on account of the great weight given to economy in ordinary engineering problems. In this connection, I would like to mention a paper which was read at a recent meeting of the New York Section by Mr. Bassett Jones, Jr. The paper demonstated the necessity of making a lighting plan conform with the general design of the building. I believe that illuminating engineers are inclined to give too little weight to these considerations.

Mr. Scheible:—In regard to the bed room with three lamps at the mirror, it seems to me that the matter of lighting has been somewhat overdone. Most of us have not even become familiar with the use of a bracket lamp on each side, and I found a case recently where a single drop lamp with a powerful reflector gave surprisingly good results, but it seems to me that three of them would not be needed in any ordinary case.

Mr. Ludwig Kemper:—Undoubtedly all of us, especially of the smaller cities, have looked with a great deal of interest on the house of the Commonwealth Edison Company here. It is very beautiful, but it is not an equipment that can be used in the small towns, simply for the reason that there is nobody in town that can afford to pay the cost of an outfit of that kind. Now, what we would like to hear is what the local company here is doing in wiring and installing fixtures in houses for people of moderate means, or even of small means, because that is the case with which we have to deal every day. The other case is more or less exceptional.

Mr. Jones:—We wire a finished house complete and furnish first-class fixtures, spreading the cost over a period of two years. This plan is proving very popular. We have contracts for both first-class large houses and small cottages. All fixtures are first-class but some are heavier and a little more elaborate than the

others, although the entire line is plain. We have been carrying on this campaign for the last few months and have contracted for about 5,000 lamps, mostly in small installations. The work is done in a first-class manner, the wiring being run in either flexible or rigid-iron conduit, as the case may require. The average cost of wiring on the deferred payment plan is about $7.50 a lamp, including wiring and fixtures.

Mr. Scheible:—There is one point I have not heard mentioned here tonight in regard to this exhibition suite of rooms, and that is the evident departure from the old gas arrangements in many of the rooms. I was all the more impressed with it, because a few days ago in going through a series of patents on electrical fixtures, dated about twenty years ago. I found that almost all of them refer to ways of attaching electric lamps to gas fixtures or combining them so as to make the two together, and I think most of the houses we go in nowadays are suffering from that practice. Many of the lamps in this house are located where it would be impossible to use gas without seriously blackening the ceiling.

Mr. J. M. Strasser:—With reference to combination fixtures for resident lighting, I find that in recent practice the gas openings are entirely separate. The architect almost always specifies that gas openings shall be separate openings (especially in the larger and more modern residences) and not made combination. In a bed room, for instance, that has three or four electric lamp openings, that room may have one combination fixture, but in a great many cases gas fixtures will be specified separately. In this way there is obtained a very good arrangement, and at the same time the customer has gas for use in an emergency. Five or six years ago there were very few architects who gave the builder or property owner much assistance in finding the best distribution of electric lamps, but in the past few years or so, it has been very different. The fact is that better results are being obtained because architects find it necessary to employ electrical engineers in their drafting department. I also find that the illuminating Society has been of great assistance to the Central Station men in advising as to the distribution of light.

Mr. Scheible:—Mr. Cravath criticised table lamps in the bed room. May I ask how he would arrange them?

Mr. Cravath:—I would install a 16-c.p. lamp with a globe which does not diffuse any better than the slightly frosted chimney used on other lamps on a table lamp. Of course it is in keeping with the rest of the glassware, but it should not be encouraged by us as illuminating engineers. Dense opal or art-glass shades should be used over table lamps. In the ordinary bed room, however, there is not very much need for portable lamps. In this case I suppose they were put in there for appearances sake.

Mr. H. V. Von Holst:—The architect does not design the lighting just to fit his own taste, but he takes into consideration the taste and the mode of living of his client. Furthermore, some interiors of residences are brilliantly illuminated and others are kept in mellower light. In planning lighting, therefore, the architect has to take into consideration the color scheme, the general design and scheme of decoration, and the desirability of diffused lighting having spots of light by means of fixtures or a combination of the two. First of all, however, he must be familiar with the different schemes of lighting, he must know the different reflectors, shades and lamps and their proper uses, in order that he can plan the most efficient and up-to-date lighting. With this fundamental knowledge—a knowledge he can well acquire by contact with a Society like this—he will be able to design in harmony with the decorative scheme of the various interiors. From my point of view I am very glad that I belong to this society, and I think the architects are going to see more and more the importance of the scientific, economic and aesthetic study of lighting schemes, such as is advocated and encouraged by this society.

Mr. C. R. Gilman:—One of the most important lamps in the "House Electrical" has not been mentioned, namely, a reading lamp, situated either over, or at the side, of the head-board of the bed. When a man comes home tired at night I know of no electrical device that gives him more satisfaction than a good reading lamp over his bed. Moreover this lamp, conveniently controlled by a switch or long chain pull socket, becomes invaluable during an emergency.

Mr. C. A. Howe:—The reading lamp in the bed room commented on has been misplaced. In the nursery over the child's

bed there is a reading lamp that perhaps should be in this room. Since the nursery is for children under the reading age, I am unable to appreciate why there should be a reading lamp over the bed in this room.

Mr. Kemper:—In the average house the lady is the boss. Now, in many places, the house is cleaned twice a year, which means not only cleaning the house, but a general tearing up and moving around of chairs and beds, dressers, and everything. The result is that in the spring and in the fall wire men are kept busy moving brackets all over the house, which is a very unprofitable business. Then when the customers get the bill they kick about the cost for moving the brackets. This explains why we do not favor brackets.

EFFECTS OF LIGHT UPON THE EYE.

By Dr. H. H. Seabrook, *Member.*

It is manifestly impossible to know what effect light may have upon the eye without knowing something about the structure of the eye. In the schematic anterior-posterior section of the eye presented in Fig. 1, and the description thereof only enough of the anatomy is given for an understanding of the references which follow later.

The transparent anterior part of the eye, the cornea and the lens behind it, are the main factors in focussing rays of light upon the membrane lining the eyeball, the retina, forming within

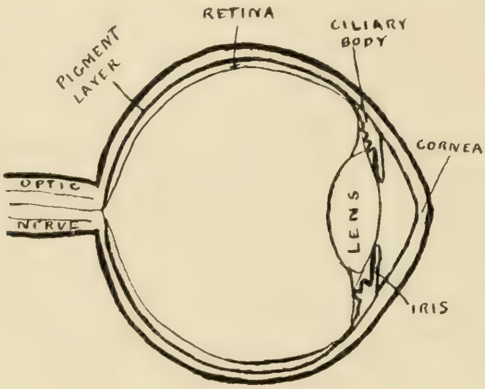


Fig. 1—Schematic Anterior-Posterior Section of the Eye.

it an inverted image of any object toward which the eye may be directed. The sensation from this image is carried by fibres in the retina and optic nerve to the brain and there interpreted according to education and experience. The posterior layer of the retina consists of cells filled with pigment which absorbs light. The whole process which occurs in the retina under the action of light is one of disassimilation, and repair takes place in the dark. The pigment layer extends forward over the ciliary processes and forms the posterior layer of the iris. The ciliary processes are folds rich in blood vessels and nerves. They furnish a low grade nutrition for the lens, and their veins must remove waste tissue, including pigment disassociated from the cells by the action of

light; when much work of this sort is required the process may be painful. The ciliary body consists of the ciliary processes and the ciliary muscle, which latter contracts and allows the lens to become more convex so that near objects may be seen. This process, called accommodation for near objects, may result in pain about the ciliary region from strain of the ciliary muscle when near use of the eyes is too long continued. As an optical instrument the eye is defective. It has chromatic aberration, spherical aberration, and other forms of irregular astigmatism, usually measurable, and regular astigmatism, and other refractive errors peculiar to the individual. These errors when not corrected cause irradiation of light with the eyeball, with consequent irritation, because rays are not properly focussed. When eyes are corrected with glasses, excessive and irregular action of the ciliary muscle is often removed, but since irradiation of light is bettered and glass filters or stops the chemical rays, the ones injurious to eyes, it is difficult to separate eye strain due to light from that due to accommodation.

That the delicate retina is not often badly injured or actually destroyed by sunlight must have caused comment among early observers in physiological optics, as the difference between heat, luminosity and chemical action from light was long ago recognized. The discovery of the composition of white light, the development of photograph, the oft mentioned similarity of the eye and the camera, and the recognition of the ultra-violet rays, evidently set men thinking anew about the natural defences of the eye against such a powerful destructive agent as light. There are three methods of protection plainly in evidence. These are partial or complete closure of the lids; the action of that circular curtain, the iris, especially when its central aperature, the pupil, is narrowed by exposure to light, and lastly, the frequent movement of the eyeball so that any one portion of the retina may not be fatigued from too long exposure to white or colored light. Anatomists exaggerated the power of endurance of the pigment layer in the absorption of light, yet even then it was hard to see how the retina escaped as well as it did.

In 1845 Brücke tried the effects of ultra-violet rays upon tincture of guiac, directly, and after passing through the media of the eye of the ox, and found that these rays were largely absorbed by the lens and to a less degree by the other media and the cornea. Donders, eight years later, concluded that the lens had no power

of absorption of ultra-violet rays, since the fluorescence of quinine solution from these rays was apparently no less when sunlight was filtered through the lens of the pig, sheep, or ox than through glass. Ultra-violet rays do not pass through glass without loss and de Chardonnet showed later that different results occurred according to species. The human lens absorbs spectral light at the H line and absorption is complete at L or M. Helmholtz, influenced by Donders, concluded that the absorption power of the animal lens was small, but when experiments were made upon animals in which the lens of one eye had been removed and that of the other left, and the electric light was brought into use, as well as sunlight, and the results upon the different eyes, as observed by many careful men, tabulated, no doubt was left as to the results. In 1904 Birsch-Hirschfeld took up the matter after nearly twenty years' time had elapsed since other investigations but with most painstaking work was able to do little more than confirm principles already established. Certain things seem worthy of mention, although only a brief general review of the results is possible here. The damage to the external parts of the eye, including the lens, is directly proportionate to the strength of current and length of exposure. With a current of three to four and a half ampères from a Finsen lamp, with the iron cooled by water so that the lamp was not hot to the skin, chemical changes were produced in eyes in four or five minutes. These were a certain puffiness and change of color of the anterior coats except the cornea, with slight cloudiness of the cornea and shedding of cells covering its posterior surface, and congestion and discoloration of the iris. The layer of cells lining the anterior capsule of the lens, from which its fibres are formed, also showed injury. Inflammation followed twelve to twenty-four hours after exposure and subsided in four or five days, although eyes were not normal for four or five weeks, even when they escaped permanent damage. The protection from the lens varied greatly in different individuals. Exposure to ultra-violet rays caused damage to the ganglion cells of the retina in one-half to one hour in eyes without the lens and with a longer exposure in eyes retaining the lens. With repeated exposures, even if the chemical light was not very intense, cataract would be formed. This opacity of the lens would then be permanent. Spectral rays of sufficient intensity cause damage, but the blue, and still more the violet rays are the really harmful ones.

Disintegration and disassociation of the cells in the pigment layer, occurring from exposure to light, are at a minimum in yellow light. A natural suspicion that heat rays cause damage to the eyes has never been confirmed; discomfort may, perhaps, be caused by them, but no tissue changes.

Injuries to the eye occur to the human race from both natural and artificial light. The best known of these is snow-blindness, due to exposure to reflected light from snow in a clear and rarified atmosphere. Chemical rays are absorbed by atmospheric dust, and the "yellow sunlight" is safer for eyes than the clear white light of the sun. To the objective signs given previously, as seen in rabbits' eyes exposed to the Finsen light, are added gritty sensations, from the inflammation of the lids, and impaired vision, or complete blindness. The same results follow exposure to strong electric light, and about the year 1890 medical journals had many reports of such cases due to the arc light. Such results still obtain, but as they occur mostly among workmen who know that the damage to the eye usually causes little if any permanent impairment of sight, medical advice is not frequently sought. Those exposed have learned how to protect their eyes better than formerly, and no doubt such cases occur proportionately less often than formerly. Exposure to direct sunlight is so evidently injurious that it is avoided, although occasionally bad results occur from recklessness in viewing an eclipse. A permanent defect in the centre of the retina, just where the sun's image was focussed, is often the result. In persons struck by lightning or where exposed to very bright electric flashes, eye troubles similar to those above noticed may occur, and an opacity of the lens sometimes results.

The severe injuries to the eyes from light already mentioned have but little practical bearing upon the work of illuminating engineers. No one expects the demand for brilliant light upon streets or in public buildings to be ignored, and the flaming arc lamps, Moore tubes and Welsbach street burners, each in its particular sphere, to be replaced by kerosene lamps. There are many other things to be considered in lighting large areas beside the eyes, which may be protected from too powerful light fairly well by frequent changes in their position and consequent rest to the exposed portions of the retina.

Illumination for near work, however, is in a most unsatisfactory state. Our country leads the world, apparently, in the bril-

liancy of its artificial illumination and certainly leads the world in ocular exhaustion, discomfort and congestion.

When gas came into general use these troubles began to increase, and a further increase was in evidence as the incandescent electric lamp came more and more into fashion. Both here and abroad, oculists agree that the kerosene burner is the least harmful artificial illuminant. They might leave the word artificial out with propriety, for no damage has been traced to kerosene light. The most satisfactory light is, no doubt, daylight (not sunlight) a few feet within a closed window on a bright day. In this light, finer lights and shadows and delicate colors may best be distinguished by healthy eyes. A greater distance from the source of light diminishes vision, and even taking away the protection of the window glass, causes more dazzling and decreased retinal endurance. The adaptibility of the eye is small for increased illumination, and the limits of increase of vision with stronger light is within the medium limits of illumination. The light should come from the rear and left and fall upon the object. If the latter has a glazed surface which reflects white light, fatigue is more rapid than with a dull surface, for below the surface of objects chemical rays are absorbed and color and visibility is due to that portion of the white light which is not absorbed but returned to the eye from below the surface.

Analyses of light, as published, are difficult to comprehend by one who is ignorant upon the subject. Daylight, or sunlight, is a variable standard to take without further definition or explanation of the conditions. Meyer's analysis, as given by Cohen, has violet in the electric (arc) light as .3 to daylight 1., and as given by Staerkle, 1. An analysis published by the Acetylene Company gives for the violet in the arc light 1. to 1. for sunlight. Staerkle gives, for gas, violet .1; Cohen, .3; the Acetylene Company, 1.15. Let us suppose that one table, giving the kerosene burner as very weak in violet rays, is correct, and another with ostensibly the same standard, omitting kerosene, is correct in giving the electric incandescent lamp what is meant to be the discredit of weakness in violet rays as compared to the other illuminants; we must then look for contributary causes which have caused the incandescent lamp to give rise to more chronic eye degeneration and disturbance than any other light used for near work. Acetylene may be thrown out on account of lack of opportunity for much damage. The image of the brilliant filament of

the incandescent lamp, with its concentration of light, must harm the retina more than the more diffuse images of flames; the benefit from ground glass globes for this light, when the eyes are exposed to its direct rays, must be partly due to diffusion of the light. Without ground glass, this light is more steadily brilliant than kerosene, gas, or the gas mantle burner, and there is less chance for retinal recuperation. Ground glass reduces all the rays of the light about twenty-five per cent. In searching for other causes of trouble, we note that the moveable kerosene lamp may be, and is usually, placed in a good position to illuminate the object, while the incandescent electric lamp is usually not well placed, often in offices being rigidly fixed so that either the eyes must be subject to direct light, or the head must be bent forward for work, congesting the eyes. No amount of green on a tin shade will correct this improper permanent position of the lamps. Again, we notice how very thin the glass bulb of the incandescent is compared with the lamp chimney, and since glass of five millimeters thickness absorbs twenty-nine per cent of the chemical rays of sunlight at an angle of 60 degrees (Hankel), we conclude we have another element of trouble, as chemical rays are absorbed by glass in proportion to its thickness.

The Welsbach mantle changes the ordinary gas flame, with its marked excess of red, to a cold light, deficient in that color. It is less irritating to some eyes than other lights, but more irritating to others.

Many substances absorb chemical rays and allow luminous rays to pass. For practical purposes there seems no need to consider any of them except glass as a protection for the eyes from the intrinsic brightness of too intense light. Neither does there seem any question that yellow is the color to choose to conserve or improve vision and protect the eyes from the chemical action of light. Globes may be used of pink, orange, red, or green, as desired, when the light may be diminished in luminous qualities. It is best to choose for protective purposes that shade of yellow which appears in the best ray filters or is shown in the glass used for modifying the light of developing rooms for photographic plates. This amber yellow may be darkened by a brown admixture for weak or diseased eyes, or unusual light exposure. It is difficult to manufacture without imperfections, and the supply slowly follows the demand.

That the study of illumination for practical purposes is difficult no one will deny. The difficulty of conveying knowledge about light, even if one possesses it, must be great, for there is no definite language, as of medicine, for instance. Newton first separated light into primary colors, and he also advocated the corpuscular theory of Descartes; and after more than two centuries we use Newton's language and speak of chemical rays in order to be understandable, and compound such sentences as "Since the wave lengths at the violet end of the spectrum are but half the length of those at the red, twice as many chemical rays as heat rays, from white light enter the eye during the same period of time." When we speak of light in general, we usually mean light with infra-red, spectral and ultra-violet effects. Light rays may mean the visable spectrum, or the luminous yellow. The expression primary colors has just been used. It meant then the seven colors to be distinguished in the spectrum by many eyes, or the six that can be recognized by the others. It is frequently applied to the fundamental pigment colors, red, yellow and blue, from which all other pigment colors may be produced by mixing; or the fundamental spectral colors, red, green and violet.

Illuminating engineers are not entirely satisfied with standards of measurement of light; they would be still more confused if the visual standards which oculists have used for many years should be presented to them. Vision for distance only has been considered, and the apparent contradictions in facts, the long descriptions of investigations by Germans, often followed by conclusions entirely at variance with the premises; the conclusions of others, especially Americans, upon no premises at all; make "laws," as they were formerly called in these studies, rather difficult to formulate. In the present instance, you are asked to believe, what many of you already know, that the desire for intensity of light has been already overdone as regards the good of the eyes. The small but increasing portion of the consumers who wish a light that is soft to the eyes ought to be encouraged.

As regards deductions to be drawn from this paper, they are not difficult. Lights weak in chemical rays are better suited to the eyes than others. Present lights may be improved by attention to position, including the distance of the source of light from the

eyes, as measured by the course of the rays, and protection of eyes by glass properly colored.

Take the spectrum of daylight through a window, and that of kerosene, argand, Welsbach and incandescent electric lamps, from just where you would sit to use them for near work, see what shade of amber yellow glass it takes to cut off the blue and violet rays, and you will find under those conditions the kerosene burner at one end of the list and the incandescent filament at the other.

Discussion of Dr. Seabrook's Paper Before the New England Section.

Mr. J. S. Codman:—This paper has brought up a matter that has not been much considered in illuminating engineering. A great deal of stress has been laid upon the efficiency and proper directing of light, and the question of diffusion with ground glass globes, etc., has been considered somewhat, but the question of color has been comparatively little taken up, and this paper is therefore very welcome.

Dr. Louis Bell:—The paper is exceedingly welcome here, as calling strong attention to the necessity of taking care of our eyes in the way of due protection. Perhaps the one particular thing to which I was very glad to have Dr. Seabrook call attention was the chemical side, so to speak, of vision. People who approach problems of this sort purely from the physical side have generally travelled on Helmholtz's theory of vision, which is as satisfactory as any up to a certain point, but this has rather diverted attention from the fact that probably the action of light on the eye is photo-chemical action of some sort. Whether that is intermediary will probably be left for further discussion, but that the process itself is photo-chemical there can be no reason to doubt. Now if this is true, it is interesting to inquire as to what rays chiefly affect the eye. In other words, if the eye is photo-chemically sensitive, as a sensitized plate, to what rays is it most sensitive? That question is a perfectly simple one. It has been answered many times and all the answers where the investigation has been pursued along rigid lines have led to the same result. Regarded as a sensitive plate the retina is the most perfect case of ortho-chromatism known, because it gives good

sensitiveness over a fairly large range without any intermediary regions in which the sensitiveness is small. Ordinary orthochromatic plates usually give a weak streak in the green. The eye is most sensitive in the yellow. Consequently (and here is the important part of that programme) the actinic rays of the spectrum as regards their effect on the retina, are not the blue, the ultra-violet or the red rays. The strongly actinic rays lie in the central part of the spectrum which is the brightest. Otherwise high luminosity would be found in these other colors. From that follows another thing—that the minimum expenditure of energy produces the maximum result of vision in the central part of the spectrum, and from that follows—according to the line which Dr. Seabrook very interestingly laid down regarding the recuperative action of the eye—that the eye receives a maximum of impression with a minimum of energy when that energy is in approximately the yellow or the bright part of the spectrum. If this is so—and here I am going somewhat into hypothesis—it is altogether probable that the efficiency of the photo-chemical process is highest just at this point and again the eye should with the minimum recuperative effort recover from the effort of seeing when the light is in this central region of the spectrum. That I think is the reason for the extremely satisfactory results that have been obtained sometimes by the use of amber glass. It simply means that when the light is filtered through amber glass the maximum effect for seeing purposes is produced on the eye with the minimum of recuperative effort. This would account for the very satisfactory result of the amber glass without introducing any hypothesis whatever as to the possible effect of an excess of ultra-violet rays in sufficient quantities to do damage. Certainly the ultra-violet is most preposterously ineffective in producing vision. The luminous stimulus in the ultra-violet and blue is remarkably weak just as in the extreme red, so there is a perfectly adequate reason for the effectiveness of amber glass in shielding the eye by softening the light without introducing any hypothesis whatever as to its probable value in cutting off the blue as such. It is to be noted that the blue rays have frequently been regarded as unpleasant and harmful. How far that is true with moderate intensities I do not know. There is every reason to believe that the ultra-violet, unless it is intense, is not particularly dangerous, although it can produce very bad results, because common daylight, everywhere agreed upon

as by far the most comfortable light, is enormously richer in proportion of blue and ultra-violet radiation than any artificial save that from the quartz mercury arc, or the Finson lamp, or possibly the Titanium arc, so that a moderate amount of blue rays can hardly be considered injurious, although there is no question from experiments that Dr. Seabrook has cited that very serious results may occur. The only lamp that I know of that has produced these effects accidentally is the Heraeus quartz mercury lamp. Thus merely from the questions of energy spent on the eye, of luminous return and of probably minimum effort or recuperation, the central rays of the spectrum, the rays of highest luminosity, other things being equal, should be most satisfactory for seeing purposes; but one must not suppose that even these can be used ad libitum without some risk. I have no doubt that some of the flaming arcs which give light almost entirely in the central region would produce very disastrous results by retinal exhaustion unless the light were softened. There is another important thing to which Dr. Seabrook called attention. You may compare two shades, one of which softens the light and the other does not, and the glassmakers do not seem to understand why. For instance Dr. Seabrook mentions certain types of glass which let through a good deal of light. They will allow the outline of the filament to be seen at its greatest brilliancy. As shades, although apparently semi-opaque, they are dismal failures. On the other hand glass which looks at least as translucent may be thoroughly satisfactory. For instance, the 6-in. globes which were installed in the halls of this building have a shielding shade which really does shield, because even the bare filament of an incandescent is hid, so that the globe is practically an illuminated ball. I hope the manufacturers of glassware will take Dr. Seabrook's remarks tc heart, for we certainly need for these modern illuminants a thoroughly diffusing globe, and my experience has shown that it is very hard to find a thoroughly diffusing globe which does not cut down the light too much. I wish the glass people would read this paper and reflect.

Prof. H. E. Clifford.—There are one or two points that appeal to me as requiring more specific explanation. I am not quite clear as to the last statement in the paper, as to why it is that this particular shade of amber-yellow glass is inefficient in cutting off the ultra-violet light from the incandescent filament.

I wonder whether the list of lamps which Dr. Seabrook intends to include, placing a kerosene lamp at one end and the incandescent filament at the other, would embrace the mercury-arc lamp. I had supposed that the amount of ultra-violet light given off is in some degree comparable with the temperature, and it is difficult for me to appreciate why the incandescent filament, running at a temperature lower than that of the arc, should apparently have a greater percentage of the violet light, which is apparently unaffected by this particular absorbing medium. Again to give a specific illustration, there has been much argument in regard to the relative merits of the incandescent lamp and the Moore tube and the mercury-arc lamps, and it has been urged in some quarters that the mercury-arc lamp is eminently satisfactory to the eye, containing no red rays. That seems to be in contradiction to the results brought out in this paper which appeal to me with a great deal of force because they are based on scientific observation. It seems to me therefore that if the light from the mercury-arc lamp is restful and satisfactory to the eye, it must be due to some cause other than the absence of the red rays. It would seemingly be a result of the statement here made that the ultra-violet light in which the mercury arc is particularly rich would be extremely harmful in its effect upon the eye. This brings up again the question of the physiological effect and its bearing upon the whole science and art of illuminating engineering, and I can only repeat what I have said on former occasions, that papers of this character are extremely important to this society.

Dr. Seabrook.—I would answer your question if I could, but the fact is I know practically nothing about the mercury-arc lamp. As regards the other question, I will try to answer that, and this will perhaps answer also one of Dr. Bell's questions. The paper dealt with the lamps which had been most in use for reading, etc. Up to the time of writing this paper, for which I could make no extra preparation, I had only an experience with these lamps, and with the ordinary spectroscopic examinations which the photographer uses, and with the cutting off of the blue and violet rays by some medium such as the yellow glass. As regards the arc lamp, I left that out as being undoubtedly more trying to the eyes. It was long ago rejected for reading purposes, so that it did not enter into consideration.

Regarding the subject of daylight, if the standard of daylight of Helmholtz is taken, this modified light on the north side of the house where the sun does not shine, I do not find by my somewhat crude methods that this daylight is as rich in chemical rays as even the light from a gas lamp. Mr. Miller presented a chart in New York showing that in daylight the percentage of chemical light is larger, even after passing through several glass prisms. Now of course diffusion of daylight makes a difference, but there is no difficulty in cutting off the violet light with the number-three amber yellow glass, with daylight as I have put it here. Consequently it is not as rich in that way as the light from the Argand burner and the incandescent lamp. I cannot reconcile weak chemical action of light from the incandescent lamp as we use it with the extreme difficulty in cutting off the violet rays. One can produce perfectly good results if the lamp is at a distance from yellow glass, but not in the usual position for near use. The light of the incandescent is, if you choose to say so, attacked here as injurious, because the lamp has come into such common use. It is a lamp which has come to stay, I suppose, and with all the investigations and improvements in effects there must be some way of eliminating the injurious effects and to find some proper method, if I have not suggested one.

Prof. H. E. Clifford.—According to the results stated it would appear that a light rich in red rays and longer wave lengths is less injurious to the eye than those rich in shorter waves. I want to ascertain whether that is the firm belief of Dr. Seabrook.

Dr. Seabrook:—It is not my firm belief that the longest wave lengths are best, and I base that on the fact that the red rays have not the same luminous properties as the yellow. Photographers have much less discomfort in developing with yellow light, and red is not a comfortable color for the eyes. I did not mean to claim that gas, first brought into use 115 years ago, is an ideal illuminant. It is a flickering illuminant and might be better. I thought that gas has had enough said against it and was being pushed to the side perhaps. I do not know whether gas is rich or not in the violet rays. It is certainly rich in the red rays and it gives discomfort to some eyes.

Prof. Clifford.—I would like to ask whether there has been any investigation in regard to the relative disintegration of the cells for the so-called chemical rays?

Dr. Seabrook:—As compared with the red or heat rays, no; luminous rays, yes. They do not cause the same disintegration.

Prof. Clifford:—Is there any means of comparison of the effect of the light containing an excess of the long waves as contrasted with the shorter wave lengths?

Dr. Seabrook:—Only as shown by other persons. Some eyes are more sensitive to heat than the thermometer would show. Sensation in the human body cannot be measured by any instrument.

Mr. A. T. Sampson:—Does the high intrinsic brilliancy of the filament and its close contact to the eye enter as causes for the damage done by incandescent lightning? Is it not the case that in the mercury-arc lamp there is less intrinsic brilliancy due to the larger surface?

Dr. Seabrook:—There is a low intrinsic brilliancy to the mercury-arc vapor. The high intrinsic brilliancy probably has a great deal to do with the damage. I think in the damage from the light of the incandescent lamp, as I have observed it, a great deal of the trouble comes from faulty position. When the light falls upon the object properly there is not much trouble. This is one of the most important things of all perhaps. I did not dwell upon that, as I suppose it to be generally known.

Dr. A. E. Kennelly.—This paper is of marked importance to a body such as ours, which has the peculiar position of combining engineering with the industrial regulation and supply of the commodity light, which is a physiological stimulus. It is of the greatest importance that we should keep in touch with the information which physiology may have to convey to us upon the action of light on the human eye.

One of the most extraordinary changes which modern civilization has brought about has been in regard to the intensity of illumination, and the total quantity of artificial light which

we employ. Looking back upon the portraits, descriptions, and models of lamps which were used by our forefathers, it is evident to the illuminating engineer that the total quantity of light employed in a room two or three centuries ago must have been relatively very small, and the average foot-candles in buildings must have been microscopic in comparison with those now ordinarily employed. Every decade and almost every year of the last two decades has seen a steady increase in the average illumination during the working hours of the night, and has seen an increase in the number and power of the illuminants which engineers have been able to supply at a price within general command. It occasions no surprise that the medical men are now coming forward to tell us that it is time to call a halt and that damage is being done to many eyes. It is important that we should obtain a thorough understanding from them as to the nature and extent of the evil, and that we should see what can be done to check its increase.

We learn from Dr. Seabrook's paper that red rays, which are of relatively low frequency, are not physiologically dangerous. We also learn that violet, or the shorter and relatively high frequency rays, are physiologically dangerous. No information seems to be forthcoming as to the relative physiological influence of the intermediate rays of the spectrum, orange, yellow, and green. It seems reasonable to suppose that these intermediate rays are physiologically hurtful when they fall on the retina beyond a certain degree of intensity, although not as injurious as the same degree of intensity of violet. Consequently, in considering the subject of injury to the eye by artificial sources of light, we should take into consideration the effects of the orange, yellow, green, and blue rays, as well as the influence of the violet rays in the visible spectrum.

Probably when translucent screens are applied to the eye so as to protect it from the excessive glare of artificial light, the best screen is one which arrests the violet rays, but allows the bulk of the other visible colors of light to pass through. This would be for the reason that the violet rays are least needed in working with artificial light, whereas they are the most capable of injuring the eye when in excessive intensity. It is reasonable, however, to believe that no such screen can be a complete protection to the eye that is working with great intensities of orange, green, or blue light. It is also probable that pro-

tection to the eye might be secured equally well by shading the lamps in the vicinity of the observer's eye, so as to prevent an excessive intensity of any color of illumination from injuring the retina. In other words, a man wearing tilted glasses which completely cut off the violet rays of an incandescent lamp might still be in danger of hurting his eyes if he sat at his desk immediately facing a vividly-incandescent lamp which poured a powerful beam of red, yellow, and green rays upon his retina. Would it not be probable that if this injurious incandescent lamp were moved to a position in which its light would not pass directly upon the man's eyes at his desk, or if the lamp were shaded in such a manner as to keep the local intensity of stimulus on the retina down to a safe limit, safety might be secured? Considering the fact that many draftsmen employ the blue rays of the mercury-vapor lamp without injury, it would seem that the blue rays are not necessarily injurious, unless their intensity at the eye is excessive.

If we consider Dr. Seabrook's paper as a plea for protecting the eye from unnecessary stimulus of any color, and particularly an excessive stimulus of violet, we can all endorse it heartily; but in the absence of further physiological evidence as to the safety of yellow, green, and blue light, I should not consider that injury to eyes is attributable exclusively to violet rays.

Mr. R. C. Ware.—Since the red rays undoubtedly are as uncomfortable as the violet, I should be very much obliged to Dr. Seabrook if he could settle the point whether they are injurious. Anyone who has sat in the balcony of a theater when the red foot-lamps suddenly lighted up for a sunset or sunrise scene will remember how very painful the red light was—very much more so than the white light which is commonly seen. If the red rays really are hurtful, we ought to consider them as well as for those at the violet end of the spectrum.

Dr. Bell.—Dr. Kennelly asked concerning the actual relative proportions of radiation in the light from some of the common illuminants. Sir William Abney, who made probably more measurements than anybody else in the field on the character of color radiation, gives the relative amount of blue and violet in the diffused skylight as three to one compared with the light from the open arc or with direct sunlight. In other words,

the sky is well known to derive its blue color from selective scattering of extreme violet rays, so that the diffused skylight from the clear sky is relatively about three times as strong in violet as in sunlight. It is much less brilliant absolutely, so that when the rays reach the retina the concentration of energy in the image formed on the retina is very much lower in the case of the skylight than it is with the light from any of the artificial illuminants, and I take it the power of the eye to recover from an over-stimulation would be consequently much greater as the concentration of energy was less. In other words, the less rapidly the eye has to take care of this excess of energy the more easily it recovers, which would, I think, explain the apparent ease of using conspicuously blue light such as sky light, without any difficulty at all in the way of eye strain. Whatever the character of the energy that falls upon the eye, the constructive action, if the eye is to remain in good condition, must quickly balance the destructive action which produces the photo-chemical changes which result in difficulty. If light energy falls with extreme power upon the retina, conditions might be reached where the eye could not stand it, and might break down completely, which unfortunately has been the case in many instances.

With respect to the mercury arc, one very prominent Boston oculist stated some time ago that he observed a few cases of serious injury to the eyes from the use of mercury arc, all coming from one place where the arc was systematically used, so that I am afraid we cannot quite acquit it, although it has a somewhat lower intrinsic brilliancy than the arc. When used in a glass tube it has some violet rays. When used in the extremely powerful quartz tube, as in Germany, one would imagine that the enormous excess of ultra violet rays would be very difficult to take care of.

Mr. John Campbell.—I ask Dr. Seabrook if he has made any experiments with the Tungsten lamp, and also whether he would advise anything other than the dead white of the porcelain reflectors for street lamps.

Mr. Wm. Clark.—Would it not serve the purpose about as well to diminish the candle power or intrinsic brilliancy (to protect tired eyes) as to go to the more elaborate method of

cutting off certain color rays by amber colored shades or glasses? What is the ratio of the intrinsic brilliancy of the Welsbach mantle as compared with that of the incandescent carbon filament?

Prof. Clifford.—I hope the distinction will be made perfectly clear between the physical effect due to the breaking down of the cells in the retina—that is what we may call the physiological effect, and the psychological effect, which is purely one of discomfort. There are certain lamps whose light makes us uncomfortable, not because it breaks down the cells, but for some purely psychological reason, and it seems to me that point should be clearly emphasized.

Dr. Seabrook.—Several questions have been asked which only a man who has practiced medicine for twenty-six or seven years would try to answer. Anybody else would have to say he did not know. The question as to how to make the distinction between the psychological action and the action upon the eye could not be answered directly for the reason that the retina is a part of the brain, but when we see the bull's action under a red rag we do not suppose that it is due to the effect of the heat rays in the red upon the bull's eye. The color irritates him. It may irritate his retina or his brain. The retina is really a part of the brain, so that one could not separate irritability in the case of red rays on the retina from the psychological effect which undoubtedly has been shown. That this line of thought brings up the discussion as to why red is the first color seen by an infant as claimed by one scientist, who explains that the longer wave lengths are first distinguished from the short ones, and the ancient Greeks had no color but red in their language. As regards the selection of reflectors, of course that is a question for experiment. I do not know how reflectors could be improved, but probably the surface should be slightly tinted. Books can be bettered by having a slightly brownish or yellowish-brown tint for the paper. It is well known that the eyes are less fatigued by this color. Prof. Tait, in speaking of photometry, has said that it is fundamentally impossible to find the equality of lights that have a different quality. I know of no way to have an accurate comparison of luminosity of the different colors. I believe, however, that on the lines I have laid down tonight suf-

ficient accuracy may be attained. Of course from an illuminating engineering standpoint the work is very incomplete, but outside of the fundamental inaccuracy of photometry I call your attention to one thing, both for the benefit of this section and that in New York, and that is the positive uselessness of taking daylight or sunlight as a standard without other qualifications. Dr. Bell spoke of a recent analysis, but the analysis of Cohen, Meyer, the Acetylene Company, etc., all show the electric arc lamp as containing an equal amount of violet rays as compared with daylight or sunlight, as the case may be. I do not doubt that the other analysis is superior to these, but a modified daylight standard is the point that I am inclined to insist upon. I ask you simply to consider not only the question of the injury that comes from sunlight, but the positive external injury that comes from the action of the rarified light, etc., as seen from mountain tops. I think very few persons could go out in the open air on a bright day and view the blue light of the sky for any considerable time without discomfort. We are constantly avoiding daylight at sea and on land, and yet are compelled to use daylight as a standard. Our eyes have adapted themselves to daylight and there is a good deal in that. The question of race may be mentioned as suggestive. Why are the blonde races in the cold region—why are the well pigmented races in the warm countries? The negroes do not need clothes to protect them from the sun, because the pigment absorbs the light. The eyes of the darker races are pained when exposed to light, when they have been injured by breaking down of the cells because the media do not absorb chemical light. Exhaustion of the eye may be caused by too prolonged use of the eyes, even with luminous rays alone. The pathological processes have never been proven or known to be due to luminous rays. I believe discomfort is frequently due to red rays, but tissue changes have never been caused by red rays. The puffiness about the eyes has never been proven to be due to these rays, and the reason that this has not been more investigated is because it was taken as a matter of course by the investigators that no serious trouble could come from that end of the spectrum which has the long wave lengths. I may have interpreted that wrongly, but none of the investigators seem to have believed that red rays are injurious to the eyes.

Discussion of Dr. Seabrook's Paper Before the New York Section.

Mr. E. L. Elliott.—This paper is one of the most valuable that has been presented before the Society, for many reasons, but particularly in view of the fact that alleged improvements in the production of light have been very numerous during the past year or two. I say alleged improvements, because, whereas they are no doubt improvements in point of mere efficiency, which is the point which investigators have been working for, they are of doubtful value when used in the manner that the old light-sources have been used, so far as their effect upon the eye is concerned. The continual aim has been to get whiter light. That is a natural incident to getting light at higher efficiency, that is, light emanating from an incandescent substance at higher temperature; and the higher the temperature the more blue and violet, to say nothing of the ultra violet and chemical rays, does the light contain. Some of the light-sources that have appeared within recent years have even been approximately monochromatic blue, and yet we have been assured by those who have used these new light-sources, that they have felt no discomfort to their eyes. Such opinions, however, are not always reliable.

The fact that the new and more efficient light-sources are coming into more general use brings to the illuminating engineer and the manufacturers a new problem, that is, to discover a method of modifying the light from these sources so as to reduce the elements of danger, or eliminate them altogether. Heretofore the single use of a globe was to soften or diffuse the light, so as to prevent glare; the use of a reflector to direct the rays in some more useful path than they would naturally have. But with light-sources that are rich in the harmful rays, the question of the lamp covering, whether it be a reflector or a globe, must involve a study of the absorption of the dangerous rays.

The possibility of making glass that will absorb the dangerous blue, violet and ultra-violet rays is a matter which has almost been neglected. I dare say no manufacturer of glass has given it any particular thought, at least in this country, but I see no theoretical reason why such glass should not be made.

I have observed in front of a grate fire, where surely the blue-violet rays must be very weak, a burning sensation of the

eye-ball, which I have always attributed to heat rays; this may be a mistake, but it is one of the reasons I have for assuming that heat rays are also injurious.

On the other hand, I had a serious experience with blue or violet rays, years ago, experimenting fearlessly with an arc lamp, so that I can speak personally of the bad effects of violet rays.

I am not sure that the introduction of the valuable new lamps will improve matters, for there seems to be an inclination to maintain the number of watts and increase the candle power proportionately. I have not yet heard any large claims for 8-c.p. and 16-c.p. high-efficiency lamps. There are 40-watt lamps and 150-watt lamps; what we want—and no matter how important these other matters may seem at first—what we are bound to have in the end, is the best illumination. To produce the best possible illumination from the light sources available is the particular province of the illuminating engineer, and the field, therefore, for the exercise of his genius seems to me to be a very promising one.

Mr. A. J. Marshall.—Last year in giving a series of illustrated lectures, I was compelled to stand facing a stereopticon lantern for several nights for a period of about two hours each night, with the result that after, and sometimes before, I had finished the lecture, my eyes gave considerable trouble—acute pains and severe headaches. After experimenting with various densities of amber glass, I was able to secure a set of eye glasses equipped with this glass which would permit of my facing the stereopticon without any apparent evil effect, while lecturing or after I had finished. I cannot be too strong in my praise for this type of glass when used for such purposes.

Dr. Valk.—Since the small intense electric lamp is the only illuminant which will form after images on the retina when the eye is moved about in the field of observation, it goes without saying that a too intense light will not be tolerated by the retinal elements. Dr. Seabrook has shown what degree of illumination is essential for reading, and that will not be injurious to the ocular apparatus, but we must turn to the medical side and consider what conditions of the eyes will always tolerate this con-

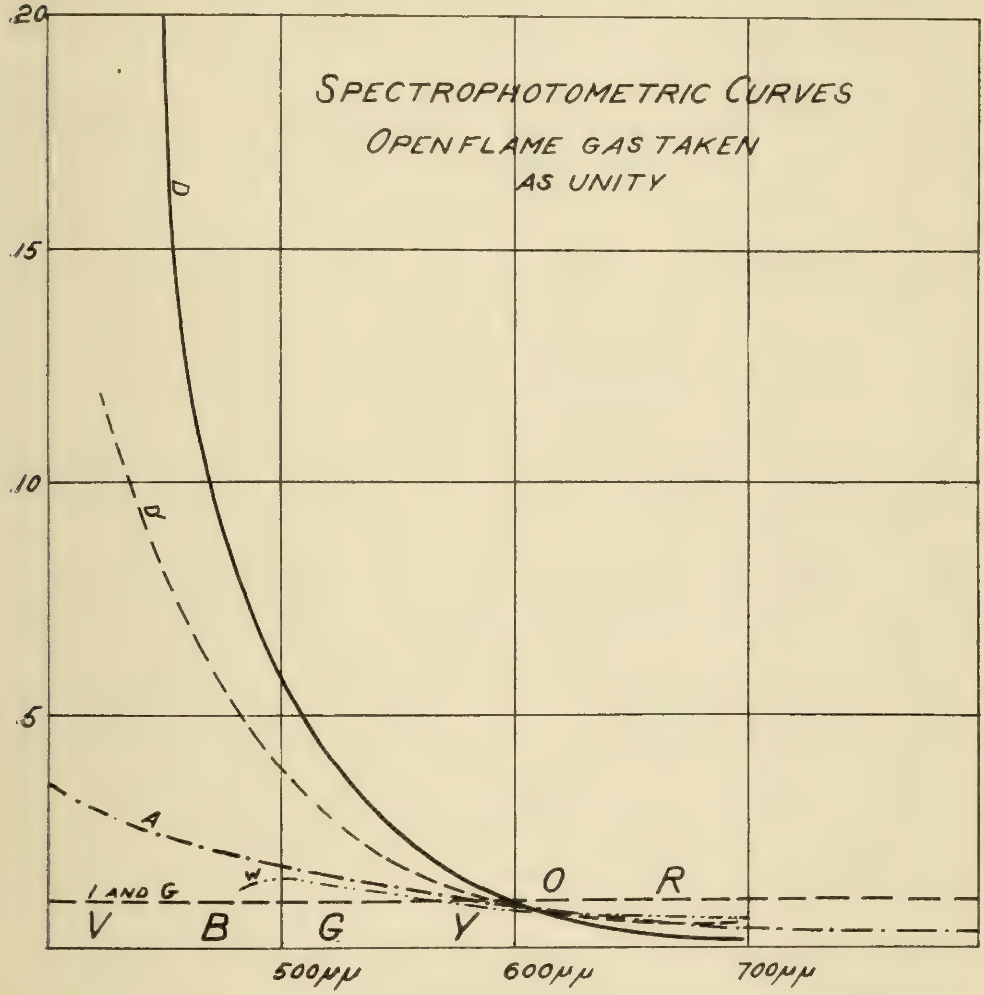
stant use. I fully believe that nature has given to some a perfect normal eye, with the retina at the proper focal distance. Under these conditions it makes little difference what may be the source of the illumination provided it is within reasonable bounds. When the eye is one with abnormal refraction there is liable to be certain symptoms of eye-strain. We, as physicians, must look to your society to give us the best and the clearest light for the illumination of our books, and we must endeavor to so correct the abnormal refraction that the eyes may be used with continued comfort. When a patient comes to us to complain of eye strains the first thing he says is "I work under an electric lamp." But we find that other men working at the same desk under the same lamp and have perfectly normal eyes, have never complained of eye strains.

Mr. Preston S. Millar.—Dr. Seabrook arraigns modern illuminants on three specific charges: First, high intrinsic brilliancy; second, bad location, and third, preponderance of short wave-length light, which he classes as "chemical rays." Now, this Society is practically committed to a campaign against light sources of high intrinsic brilliancy and against poor location of light-sources. The resultant injurious effects are recognized and guarded against wherever an illuminating enigneer does his work intelligently.

The third charge appears to me to lack substantiation. We must accept Dr. Seabrook's statement, and it is undoubtedly true that "chemical rays" produce injury to the eyes, but whether this injury occurs in the practice of modern illumination is the question in which the illuminating engineer is interested. It is not a question whether ultra-violet light thrown on the eye for experimental purposes produces these effects. The question is, does the short wave-length light as given by modern illuminants result in marked injury to the eye under the conditions of general use?

In order to consider this intelligently, I have prepared some spectro-photometric curves from a Physics Manual, which has been compiled by Prof. E. L. Nichols, of Cornell. These curves are probably substantially correct, and are undoubtedly so nearly correct that, as far as the point I have in mind is concerned, they could result in no misconceptions. The horizontal line

representing unity, is taken as the radiation throughout the visible spectrum from an open flame gas lamp. The carbon filament incandescent lamp is not discussed in the Manual, but it is so nearly identical with the open flame gas lamp, that I have ventured to group the two together on this diagram. Curve W



D – DAYLIGHT UNCLOUDED SKY
D' – " CLOUDED "
A – ARC LAMP
W – INCANDESCENT MANTLE
I AND G – CARBON FILAMENT ELECTRIC AND OPEN FLAME GAS

shows the spectro-photometric values of a "yellow" incandescent gas mantle; Curve A represents an arc lamp, while Curves D and D' represent daylight, under varying conditions as stated.

It seems to me that in view of the fact that in daylight (which has been considered by Dr. Seabrook and others as the

ideal light where the welface of the eye is concerned) we find the short wave-length light to be far in excess of that given from any artificial illuminants, one is justified in questioning Dr. Seabrook's conclusions that short wave-length light is responsible for injury to the eyes.

It has been stated that when the human eye is at rest and all muscles are relaxed, it is adjusted for distant vision; that when it is accommodated for near vision, the ciliary muscles and those which control the movements of the eyeball are under tension and are put to considerable strain. In other words, the eye is adapted to the purposes of primeval rather than of modern man. It follows that the demands of modern civilization for close application of the eyes in near vision work, over long continued hours per day, may be suspected of being at the bottom of most of this trouble. In our modern life we turn night into day and it may well be true that this fact is largely responsible for injury to the eyes, and for other effects sometimes charged to modern illuminants.

Furthermore, we find it stated that in studies of the eyesight of children, 60 or 70 per cent. of scholars between eight and nine years of age are classified as near-sighted, but that children before undertaking the school course are practically free from near-sightedness. Conclusions have been drawn by authorities which indicate that much of the defective vision found to exist at this time is the result of improper use of the eyes of children between the ages of seven and nine years.

Putting these facts together, it is fair to asume that the requirements of modern civilization in our strenuous age rather than the character and methods of use of modern illuminants are responsible for a large proportion of the eye trouble reported.

Mr. E. Y. Porter.—The gist of the whole matter is that diffused day light (not direct sunlight, but diffused day light on a slightly clouded day) is the ideal illumination. By such illumination we can see things more clearly and work more continuously with less fatigue than by any other light. Mr. Millar's data seem to show that violet light is not very harmful. It is the intensity and position of the light-source more than the quality of the light that is easy or harmful as the case may be.

It may be interesting to some to learn of the qualities of light produced by gaseous conductors under electric stimulus, as in the Moore tube. The yellow light produced by pure nitrogen which one would naturally suppose to be very deficient in chemical rays, as a matter of fact has as much actinic value as the white light produced by carbon dioxide. In fact, for equal power it has more, so that a yellow light is not necessarily devoid of actinic rays, simply because it is yellow. The color values as well as the intensity of carbon dioxide used as a conductor of electricity in a vacuum tube operated under definite conditions, can, without doubt, be made to give practically constant results.

Dr. Louis Bell.—The thing which very forcibly impresses itself on me in listening to Dr. Seabrook is that in dealing with the effects of light on the eye, as shown by the experiments which he cited, we are dealing with two absolutely distinct phenomena. In the first place there is the effect of the light on the cornea, and the merely incidental effect in reaching the retina, and secondly, there is the effect of the light on the pigmented layer of the retina itself. So far as the cornea and lens are concerned, it is quite well known that there is a considerable opacity to the extreme ultra-violet rays, even down into the violet. It is a well known fact, for example, that the eye of an elderly person is certain to be less sensitive to the extreme violet than the eye of a young person. It was one of the first signs of approaching age, one learned man said, when he could not see the H and K lines in spectroscopic work as well as he used to. The secondary effect of the lens is unquestionably to cut off a lot of that ultra-violet light. The fact that the eye is more sensitive to the ultra-violet, shows that energy is absorbed at that point, and that the eye suffers when the light is too brilliant. If the lens were really transparent to light of any wave-length, there would be no energy spent in the lens, for it is only by virtue of its absorbing power that any energy can be expended.

The color sensitive plate in the retina is prodigiously sensitive in the yellow, very little sensitive in the deep red, and very little sensitive in the deep blue. Consequently, so far as the chemical action on the retina is concerned, the chemical rays are all rays of the spectrum. The damage to the eye with which we deal can be divided into two parts, as the paper showed—first,

primary lesions, which come from a tremendous excess of extreme violet light. That is found in the quartz lamps constructed by Heraeus, some few of which have been used in this country, where the ultra-violet rays pass through the quartz almost unobstructed and produce serious lesions. Some experiments made in connection with quartz lamps were attended with serious results. The concentration of energy was very large in these experiments, and within a very short distance of the eye experimented on. Several thousand foot-pounds of energy per minute may have been poured out and converted into radiation of various kinds and hurled at the unfortunate eye. The result was a rapid disintegration on the surface. Whether the same effect would have been produced by equal concentration of energy in the visible spectrum is somewhat doubtful, but so far as the retina itself is concerned, there is no doubt whatever that the active brilliant rays of the spectrum would produce very serious results. I do not believe, for example, that anybody could safely view an eclipse through a cell containing a solution of picric acid which would cut off ultra-violet rays.

I think the tremendous flaming arcs would set up trouble at the retina, whatever they might do elsewhere, as quickly, or more quickly than the ultra-violet light. As respects the retina itself, the mischief there is largely due to concentration of the energy to which the retina is sensitive. I fancy, as far as that particular thing is concerned, a bright image in yellow would be as bad as a bright image in any other color and that is a common cause of injury, I think, both from arc lamps and such sources, and from incandescent lamps.

When a person's eyes are subjected to a flash from a switchboard, which nearly destroys his vision for some time, as far as the retina is concerned, the trouble is almost entirely due to the concentration of energy, which results from a source of high radiating power. The intrinsic brilliancy of a kerosene oil flame is low. The intrinsic brilliancy of the new incandescents is very high and it must be modified accordingly; at the expense of some thirty or forty per cent., the light of any incandescent lamp can be reduced to a brilliancy below that of the kerosene lamp. When this has been done I have hopes that the chief cause of difficulty, though not all subsidiary causes, will have been removed.

Mr. W. H. Gardiner.—It has been my fortune for a number of years to spend two or three months every year in the back woods of Maine and Canada, cruising around with Indians and trappists. I have noticed in the case of other men who go with me, men who have eye trouble of some kind and wear glasses, that after they have been in the woods or on the waters for three or four weeks, they remark on the improved feeling of their eyes. In some cases they have discarded their glasses after being in the woods for a month or so. The conditions of light are very intense. I personally have attributed this improvement to the absence of red, and am interested in Dr. Seabrook's remarks that red is not injurious to the eye. Apparently, the reason is that these men are getting back to nature, and under natural conditions their eyes have improved.

Mr. W. J. Willcox.—I have always attributed a large part of the harm which it is claimed electric light does to the eyes to the position in which the lamps are placed. The unfortunate location of lamps has been due largely to the necessity for economy. With the very low economy of all forms of lighting and the high cost of the energy supplied, it has been necessary to use individual lamps in the most economical way and to devote little light to general illumination. We can see some possible correction of past difficulties with the advent of higher efficiency lamps. With the advantage which higher efficiency gives of placing lamps at greater distance from the work, the light can be diffused to better advantage than in the past. I consider the higher efficiency illuminants as an improvement in the general condition, rather than, as Mr. Elliott seemed to think, a backward movement.

Dr. Seabrook.—I have absolutely nothing to say against the remarks of Mr. Millar, Dr. Valk and Dr. Bell, as regards the question of things other than light being responsible for eye troubles; I presented a paper to bring into notice the effect of light on the eye, not to discuss all the causes of eye strain and disease. Some oculists seem to have at last concluded that their armor is not sufficient to protect the eye against the artillery of the modern illuminating engineer, and have been trying to show where the source of trouble is. Dr. Bell showed much the same thing in his able paper of 1906, and chose a low

candle power for illumination at a certain given distance so that not over two candle power would enter the eye one foot away from it.

All experimenters have found that the absorption of ultra-violet rays by the animal lens is variable. The human lens does not properly absorb ultra-violet rays in certain persons. Of course, the effect of correction by glasses and other treatment is far more important to oculists than the study of the effect of light on the eye. If illuminating engineers wish to produce light which suits their ideas, oculists will do the best they can with its bad effects upon the eyes, if such arise; they have had to do so for many years.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. MARCH, 1908. No. 3

At a meeting of the Council, March 13, a report of the committee appointed to offer recommendations to the Council relative to the Society's relations with the Technical Press was presented. Upon consideration of the recommendatons offered by the committee, the following resolutions were laid down by the Council:

(1) That the editor of the *Transactions* shall, as far as practicable, have the paper or papers read during any one month printed in the next issue of the *Transactions*.

(2) That the Committee on Papers be authorized to copyright such papers as they may deem fit for the best interests of the Society.

(3) That the technical papers of the Society be not given out for publication until after ten days from the actual date of their presentation, and that notice to this effect be printed on the advance copies of papers.

(4) That in all publication of papers or discussions of the Society the Committee on Editing and Publication insist that proper credit for such matter be given to the Society.

The report of the Finance Committee as printed below was then brought up for consideration by the Council. In acceptance of the recommendations offered in this report, motions were made and carried as follows:

(1) That the bills payable by the Society, amounting to $227.03, be paid by the General Secretary at his earliest convenience.

(2) That the salary of the Assistant Secretary be increased to $18.00; this increase to date from January 1, 1908.

(3) That the matter of the prices now paid for stationery be looked into before additional orders are placed.

(4) That the General Secretary again communicate with those members of the Society who, by reason of adverse circumstances, have thus far been unable to pay 1907 dues.

(5) That lists of delinquent members be sent monthly to the Secretaries of the Sections, with the request that they co-operate with the General Secretary in collecting the outstanding dues of members of their respective Sections, and that the General Secretary communicate individually with those delinquent members who are unaffiliated with Sections.

(6) That the question of the advisability of reducing the number of meetings of Sections from nine to four per year be brought up for discussion at the next meeting of the Council.

By unanimous vote of the Council, the entrance fee of the Society was waived until the beginning of the fiscal year 1909. The General Secretary was instructed to communicate with those members who have paid the initiation fee, and—if application of the remittance to 1909 dues be undesired—to refund the payment.

Letters relative to the withdrawal of the Pittsburg Section, received from the Vice-President of the Society representing the Pittsburg Section, and from the Committee appointed to investigate the Pittsburg Section conditions, were read before the Council. It was resolved unanimously by the Council to discontinue the Pittsburg Section of the Society.

The attention of the Council was brought to the matter of the communication received from the Chairman of the Committee on New Membership of the New York Section, requesting an appropriation of $250 from the General Treasury to conduct a

local campaign of circularization to increase the membership. It was moved and carried that the General Secretary notify the New York Section that while the Council urges the necessity of increasing the membership by such means as are practicable, it is impossible, on account of the financial status of the Society and the need of treating the Sections on similar basis, to grant the appropriation.

It was resolved that the Treasurer be given full power to accept the Receiver's Certificate of the Society's funds on deposit with the New Amsterdam National Bank, and to make assignment of the same to Mr. Lansingh.

By vote of the Council, the following five men, whose applications had been duly approved by an Examining Board, were declared elected:

HERBERT W. ALRICH, Engineers' Assistant, Consolidated Gas Company, New York City.

N. A. DUTTON, Philadelphia Branch Manager, Edward Miller & Co., Philadelphia, Pa.

CLARENCE W. KINNEY, Consulting Engineer, associated with Coghlin Electric Co., Worcester, Mass.

RALPH C. RODGERS, Instructor in Physics, Cornell University, Ithaca, N. Y.

MARVIN SHIEBLER, Gas Engineer, associated with Stone & Webster Engineering Corporation, Brooklyn, N. Y.

CHICAGO SECTION.

The Chicago Section met in the Breakfast Room of the Grand Pacific Hotel on Thursday, March 12. A paper by Mr. George Leland Hunter, on Light and Color in Decoration, was read by the Secretary, Mr. George H. Jones. The paper is printed in this issue.

PHILADELPHIA SECTION.

A meeting of the Philadelphia Section was held in the Auditorium of the Philadelphia Electric Company on March 20, seventy members and thirty-one visitors being present.

The papers of the evening were "Modern Methods of Illumination from the Architectural Standpoint," by Mr. Horace W. Castor, and "Lighting Fixtures, from a Manufacturer's Point of

View," by Mr. F. C. Dickey, the latter paper being read by Mr. David Vickery. Both papers were well received and provoked a spirited discussion by Messrs. Emile G. Perrot, architect; Mr. Clayton W. Pike, Mr. Ely, Mr. W. H. Gartley, Walton Forstall, Bond, Israel, Koockogey, Eldridge, Dutton, Lloyd, D'Olier, Calvert and others.

NEW ENGLAND SECTION.

At a meeting of the New England Section, held on March 17, Dr. Myles Standish presented a paper on "Artificial Illumination from a Physiological Point of View." The paper was discussed by Chairman Codman, Messrs. Ware and Griffin and by Drs. Williams and Standish.

NEW YORK SECTION.

The meeting of the New York Section, held on March 12, was devoted to the presentation and discussion of a paper by Mr. E. L. Elliott, entitled "The Relation of Illuminating Engineering to Architecture, from the Engineer's Standpoint." The discussion was participated in by Messrs Basset, Jones, Jr.; L. B. Marks, F. J. McGuire, W. H. Gardner, Jr.; A. J. Marshall and the author.

ANNUAL REPORT OF THE FINANCE COMMITTEE.

To the Council of the Illuminating Engineering Society:

In accordance with the provisions of the Constitution, the Finance Committee has, during the past year, exercised direct supervision over the financial affairs of the Society. It has examined and approved all bills paid by the Society. The financial condition of the Society at the end of the fiscal year 1907 is shown in the subjoined report of Messrs. Peirce, Gimson & Co., certified public accountants, who were employed to audit the books and accounts of the Society.

Exhibit "B" of the audit shows the following expenses for the year 1907:

Expenses, General Fund	$5,202.16
" Special Fund	943.79
Grand total	$6,145.95

The Special Fund referred to above was collected to meet the expenses of the Boston Convention, held July 30-31, 1907.

Exhibit 'B" shows that the total membership dues (collected and outstanding) for the year amounted to $4,234.20.

Thus the expenditures from the General Fund of the Society were about $1,000 in excess of the membership dues. Were it not for the income derived from advertising in the *Transactions,* the Society would not face a considerable deficit. Unless the membership is very materially increased during the coming year, and running expenses kept at the lowest practical limit, we must again look to the income to be derived from advertising or from sources other than dues, to meet partly the expenses of conducting the Society. The present membership is 943. With dues of only $5.00 a year the Society should have a membership of at least 1,500 to provide sufficient funds to carry on its work properly along the present lines.

Distribution of Expenses.

The expenditure per member from the General Fund of the Society for the fiscal year 1907 was distributed as follows:

For transactions (net)	$2.55
" General office (including postage and salary of Assistant Secretary	2.03
" Sections	.93
Total expense per member for year 1907	$5.51

Respectfully submitted,

A. A. Pope,

Geo. G. Ramsdell,

L. B. Marks, *Chairman.*

Exhibit "A"—Balance Sheet for year ending January 10, 1908.

Assets.

Cash in bank	$272.24
Members dues, 1907, outstanding	42.50
Advertisers' accounts outstanding (net)	193.73
Office furniture	218.02
Society badges on hand	30.00
Total	$756.49

Liabilities.

Members dues, 1908, paid in advance	$60.00
Expense bills unpaid	30.00
Total	$90.00
Surplus per Exhibit "C"	$666.49
Total	$756.49

Exhibit "B"—Income Account for the Year Ending January 10, 1908.

Income.

Members dues for 1907 collected		$4,191.70	
Members dues for 1907 outstanding		42.50	
			$4,234.20
Advertising—Collected		862.66	
Advertising outstanding (net)		193.73	
			$1,056.39
Profits on badges sold			30.10
Convention fund, receipts		$962.90	
Deduct, expenditure.			
Publication expense	$344.64		
Publicity and correspondence	180.00		
Expense of exhibits	17.95		
Badges	46.88		
Crossman, T. E., official stenographer,	111.90		
Assistant Secretary	42.42		
Misc., including expense of Committee on Entertainment	200.00		
		$943.79	
Unexpended balance			19.11
Total income			$5,339.80

EXPENSES.

"Transactions"	$2,464.26		
Less received for copies sold	54.90		
		$2,409.36	
Postage		257.37	
Office salary		810.00	
General Office expenses		846.91	
N. Y. Section	$327.69		
Chicago Section	207.56		
Boston Section	165.93		
Philadelphia Section	85.69		
Pittsburg Section	91.65		
		$878.52	
Total expenses			$5,202.16
Balance, net income			$137.64

EXHIBIT "C"—SURPLUS ACCOUNT, JANUARY 10, 1908.

Balance to credit as per books, January 14, 1907	$93.23
Add.	
Office furniture (not entered on the books)	218.02
Members dues, 1906, collected in 1907	222.60
Net income for 1907 (per Exhibit "B")	137.64
Total	$671.49
Deduct.	
Difference in bank account as of January 6, 1907	$5.00
Balance to credit of Surplus Account January 10, 1908	$666.49

LIGHT AND COLOR IN DECORATION.

By George Leland Hunter, *Member*.

I must begin with an apology for reading a non-scientific paper before a scientific society. I shall not try to tell you how much but what. My conclusions will be entirely qualitative, never quantitative—which according to Herbert Spencer is the difference between common knowledge and science. Common knowledge tells us that a piece of wood will float on water. Science tells us how much water it displaces. The savage knows that a burning torch gives light. The illuminating engineer is able to calculate how much light it gives and to prove from it the often-quoted but little-understood law of inverse squares.

For the work that has been done by the members of the society, I have the profoundest admiration. A mass of facts is being assembled that will ultimately substitute science for guess-work and experiment, in the art of illumination. To no one will these facts be more important than to the decorator and architect. But permit me to suggest that without decorative co-operation the full value of your science cannot be realized in practice. You will accomplish economy and calculated efficiency, without achieving beauty and comfort and real efficiency.

It is a great pity that the word "decorative" is so generally misunderstood. From remarks made before this society one might infer that decoration is synonomous with ornamentation and that decorative lighting means the employment of highly wrought chandeliers and fixtures. Nothing could be farther from the truth.

Decorative lighting is illumination that is aesthetically satisfactory—the light being so distributed as to avoid violent contrasts of light and shadow, while displaying objects in a manner agreeable to the eye. Lighting to be decorative must be efficient; but it must be more than that. It must be in good taste. The ignoramus is no more a judge of good lighting than he is of a good painting.

Light is the most marvelous fact in life. When the sun rises in the morning, he summons every living creature to activity.

He transforms black chaos into fields and rivers and mountains and cities. He distributes color from a generous palette, investing each object with hue and tint, to show its form and give it individuality.

For thousands of years men stumbled along on moonless nights with torches and candles, and with open lamps without chimneys that burned heavy oils. The artificial illumination that dazzled the court of Louis XIV was ludicrously dim.

At the end of the eighteenth century the oil lamp was improved by the addition of chimney and forced draft. In the first quarter of the nineteenth century coal gas was welcomed as the most wonderful achievement of centuries. When the allied sovereigns of Europe met in London in 1814, they were thunderstruck at the illumination that "turned night into day." In the middle of the nineteenth century, kerosene came to supplant inferior and more expensive oils.

In the last quarter of the nineteenth century the electric light was developed to a point where it is possible to light interiors brilliantly, conveniently, safely, and decoratively. In actual practice, however, the possible has seldom been accomplished. The art is still too new and the tools are still too unfamiliar. And progress has been hindered by adages that merely through repetition have come to have authority.

Especially is this true in color. Some ignoramus once asserted that warm colors should be used in rooms with north light, cool colors in rooms with south light. Sounds plausible, doesn't it? Warm colors to warm up the cold rooms, cool colors to keep the south rooms from being distressingly hot. What are the facts?

The facts are that for north rooms blue and green are exceedingly agreeable, while reds are disagreeable. The opposite is true in south rooms. Yellow is cheerful in both. North light coming from the sky is bluish, while south light ranges on a bright day from red through yellow to white and back again as the sun sinks in the heavens. In north light, reds look muddy; in south light, blues are apt to be cold.

This brings us to a law that is grotesquely violated in general practice as well as in the advice given to their anxious readers by the cosy-corner editors of the how-to-do-it-yourself-magazines: In illumination avoid strong color contrasts. A pretentious café in this city has walls in dark-red burlap, with wall

lamps carrying green shades. The proprietor explained to me that the green of the shades was intended to counteract the redness of the walls. Of course, the result was awful—blotches of pink where the unshaded light struck the burlap, with dark and muddy redness elsewhere. If the shades had been red the redness of the walls would have been diminished instead of being accentuated. The effect of the green shades was to cut off the red light that alone could render service on a red background.

Yellow shades would also have been possible, because yellow is the color easiest for the eye to handle. It comes in the middle of the spectrum, and has a wave length that all eyes can easily apprehend. The colors at the ends of the spectrum are more difficult. Some eyes are better for the long wave lengths of red, others for the short wave lengths of blue light. The result of my personal observations is confirmed by the work of different individuals on the photometer. Some have eyes more sensitive to reds, others have eyes more sensitive to blues. Apparently there is a color range of the eye just as there is a pitch range of the voice.

Cooler charts I abhor, and systems of color that deduce quantitative results from qualitative analysis are ridiculous. But the formerly wide acceptance of the famous color or chromatic circle of Chevreul renders it imperative to explain why M. Guiffrey, the present director of the Gobelins, where Chevreul had charge of the dyeing for a considerable part of the nineteenth century, speaks of the chromatic circle as "based on empricism, guesswork and a different visual aptitude in every individual." Chevreul started with red, yellow and blue as primary colors, and by intermixing, and by mixing with black, arrived at no less than 14,400 tones, not to speak of twenty grays that he called normals.

In his circle, red is 120 degrees from yellow, on the left, and the same distance from blue on the right. We need go no further. Such an arrangement is not only not based on the facts; it contradicts them. Red as a form of visible motion is the antithesis of blue. The wave length of red is long, of blue is short. The two colors have nothing common except nearness to black. Beyond red the wave lengths are too long for the eye to apprehend; beyond blue they are too short. Hence darkness beyond both. Darkness alone brings red and blue together; light separates them.

The solar spectrum arranges the colors for us in order of wave length and tells us that all of them united look white, the absence of color being black. I would suggest the accompanying diagram as presenting the facts clearly and truthfully.

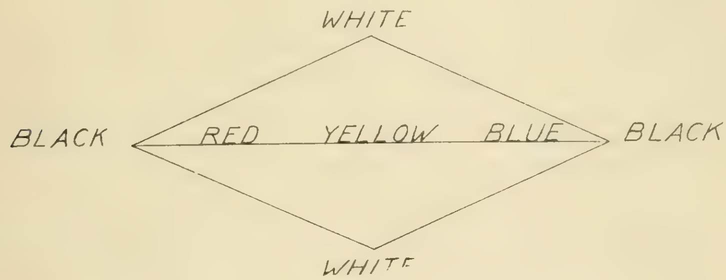


FIG. 1—COLOR DIAGRAM THAT PRESENTS THE FACTS

The color nearest white is yellow. It is the color of medium wave length, while white is the union of all the visible wave lengths. It contains only the wave lengths easiest for the eye to apprehend, while white contains also reds and blues to which some eyes are less sensitive. Perhaps this is the reason why yellowish light, like that of the kerosene lamp, is so arranged to the eye.

The white light of the noonday sun blinds the eye. It continues to blind the eye when reflected from white snow or white sand. But when reflected from the green woods of spring, or the yellow-brown woods of autumn, or from blue sky and water and from brown earth, it loses its fierceness.

The sun that creates the colors, also devours them. He calls them into being in the golden morning, only to overpower them at tropical noon with his midday whiteness. But as he sinks in the western sky, they revive and in the twilight assume a mysterious and elusive beauty.

Interesting, too, are the grays and blues and purples that tinge the atmosphere when it is wet with fog or mist. And the harmonies made by clouds beneath a setting sun or silver moon are wonderful.

As in natural light, so in artificial light, color is vitally significant. But we must include not only hues like red and yellow and blue, but also the tints and shades of gray ranging from white to black. They are vastly the more important for revealing the form and relative position of objects. For with them stronger contrasts can be obtained. They traverse the whole distance from white to black, from light to darkness, while the

hues make only part of the trip, and weakly. In illustration, white and black without hue are tremendously effective; but the hues, ungreyed, are speechless.

There has been much written and printed about advancing and receding colors, uselessly. Whether colors advance or recede depends on the situation in which they find themselves. Against a dark back-ground, as at night, lights and light colors advance. Against a light background, dark colors advance. Tints and shades push each other violently apart. Black type stands out against a white page; and so does white type against a background of black paper, which, in turn, would stand out from a white wall.

The different hues also repel one another. Red pushes away green, and yellow pushes away blue, while red and blue are still more active against each other. But they can be easily reconciled and there are no hues that by the use of a dominant color cannot be coaxed into propinquity.

Hues all look alike on dark nights. Taking the light out of them—or mixing them with black if they are paints—obliterates distinctions. Mixing white with them does the same. Red and green when pure, as in the spectrum, or when nearly pure, as in some pigments, are bitter enemies. But pinks and grey-green dwell together in peace and harmony. Yellow is a most satisfactory dominant on account of its cheerfulness. The most wintry landscape seen through yellow glasses grows warm. Blue glasses produce the opposite effect. Even autumn foliage loses its warmth when viewed through them.

Mass is the result of color contrast. The shadow on the side of the tree away from the light, contrasting with the brightness of the near side, gives the tree solidity. Against a background of blue sky, green fields and forests stand forth; and against them appear the soldiers in red, forced into the foreground by contrast.

To eliminate light and shade is to eliminate mass and to make solid things look silhouetted. To introduce hue and shade on a flat surface at once simulates the massiveness of actuality. The degrees of contrast are regulated by the amount of opposition necessary to round out shapes and separate foreground from background.

It is the task of the decorator to confirm what is good and correct what is bad in the work of the architect. If the windows are too high and narrow, the defect must be overcome with

draperies. If the room is too wide and low, he must raise the ceiling and bring down the walls. He is like a painter who with the colors from his palette must follow more or less closely the outline drawing of another.

In the decoration of interiors hue is important, but light and shade are more important. All should be used discreetly and in moderation. Violent contrasts are dangerous.

If the ceiling is the right height for the large rooms on a floor, it is too lofty for the small rooms. How shall we lower it?

Light walls recede and dark walls advance. Keep the ceiling and floor dark and the side walls bright. The ceiling and floor will at once approach each other, while the side walls will open out.

If a room is too wide and low, give it the opposite treatment. Light the ceiling brightly, and the side walls dimly, and the floor less than usual. But do not overdo the contrasts, and remember that the floor should always be comparatively dark in order that it may seem solid beneath the foot. People slip on parquet floors because the surface looks insecure, rather than because of its slipperiness. The darker its colors and the more intricate the pattern, the more solid will it seem. Rugs are a good floor covering because the pile absorbs so much of the light that they look opaque.

Doors and windows and mirrors are everything to a room. They open up the walls in which they occur, and the apparent expansion is proportionate to their size. For this reason a low room should have them small, and a high room should have them large. Take the connecting front and back parlors so common in New York city. The windows at the front and the wide doorway at the back tend to exaggerate the awful length. They must therefore be heavily draped in dark colors with plenty of embroidery or other small pattern—for small patterns tend to make surfaces advance. The doorways on the side next the hall are a help, and should be kept as free from light-devouring fabrics and patterns as possible. The walls of the room should be hung with paper of large figure, or plain and light color, and large mirrors and pictures should be employed freely. The lamps should be so placed as to light the side walls more brightly than the ends of the room. Chandeliers and hanging fixtures will do this best if the ceiling is high; well brackets if the ceiling is low.

I have been trying in vain to understand why so much effort is being exerted to illuminate interiors without wasting light on ceiling or walls or refractors. Is it possible that any one fails to realize that reflecting surfaces and refracting media that make the light useful by changing its make-up and lessening its intensity, are imperative? Can it be that they are serious when they lament the loss of the light that goes to the ceiling? Do they not appreciate that to illuminate a room is the same thing as to light its walls and ceiling and furniture, and that the light thus employed is usefully employed? Or is it possible that they still believe in the virtues of pure white light, and fancy that the object of a lamp is to send light directly to the eye?

The light that reaches the eye directly is not of the slightest use. You don't want to see the flame, you want to see the room and the people in it. Besides, the light hurts the eye, even when reflected from a mirror, and is agreeable only when its intensity has been lessened by reflection from some surface, or refraction through some material that eats up part of it. The reflected light is less in quantity, having lost some of its colors, but the colors that remain are those that identify the thing seen, and make it visible.

In looking over a recently published book on illumination problems, I was surprised not only at the ugliness of the interiors and lighting fixtures illustrated in the chapter on residence lighting, but also at the illustrations appearing in the chapter on demonstration room tests. Of the twenty-six cases illustrated, the only one that shows an effective light distribution is the one with the bare lamp. In most of the other cases reflectors and refractors of various types have succeeded in taking the light from ceiling and upper walls that can distribute effectively, and in concentrating it on the floor where it is objectionable. Not that I would for a moment deny the value of prismatic shades and globes in many instances—especially where a room is too high and the plane of illumination really needs to be lowered. But often ignorance of the importance of walls and ceiling in light distribution leads to serious and expensive error.

Here comes up the question of the color of walls and ceiling. If they were in black velvet, they could not assist us in the illumination of the room. But if they are in ivory—not white, that is disagreeable to the eye even in the weaker form that we get in reflection from plaster—they will not only distribute the light

agreeably and economically, but will themselves be cheerfully visible—which would seem to be desirable.

A small room of good proportions with light walls and ceiling is beautifully illuminated by two sixteen-candle-power bulbs suspended from the centre of the ceiling about six feet six inches from the floor. In large rooms the light of lamps as low as that would strike the eye unpleasantly, especially as their power would of course be greater. Only in rooms with high ceiling where the lamps can be hung high is the use of powerful units permissible.

The candle power of the light source is directly regulated by the height of the ceiling. The light that blinds the eye at three feet is harmless at nine, having lost eight-ninths of its intensity. In a huge auditorium like that of Madison Square Garden, lamps of enormous power can be effectively used. In interiors with low ceiling the units must be kept small.

Another way of preparing light for the eye is to refract it through frosted or opal or mosaic glass, or through crystal beads or prisms. This turns the lamp from something to be avoided into something that the eye likes to look at, and at the same time it transforms glare into diffused light. The refractors play the same part as ceiling and walls, and would help to illuminate even a room in black velvet. The use-efficiency of a lamp that distributes light cannot be compared on the basis of photometric tests. The light that counts is the light that is actually employed in the revealing of objects to human vision. And I may suggest that for general illumination, three feet, so often employed in photometric tests, is lower than the plane of greatest usefulness for general illumination.

The color of lamp shades and refractors is highly important. Those in golden yellows, ambers and light-browns are safe almost anywhere. In a red room, blue or green shades should never be used, nor red shades in a green room. As I have already intimated, rooms finished in dark colors are almost impossible to illuminate brilliantly, and look best when kept comparatively dim. Whether the room be light, or dark, the material of the lamp standards and fixtures should never be dark enough to contrast strongly with the lights. A chandelier in hammered iron in a classic Colonial room is an atrocity.

In the past there has been much complaint about the greenness of the light from gas mantle lamps and the blueness of light

from the mercury vapor lamps. The method sometimes suggested to cure the color is to use shades, or to finish the rooms, in contrasting colors, which is the opposite of what should be done. A mantle lamp in a green room loses its greenness entirely; and in an interior where green and blues abound, as in a palm garden, the hue of the mercury lamp is not unpleasantly noticeable. This emphasizes my contention that strong contrasts in hue or light and shade should be avoided. There does not appear to be anything intrinsically disagreeable about ultra-blue light for the eye that is used to it. Only when accentuated by contrast does it offend. This suggests the answer to a question put to me recently by a young man who asked how he could learn to see the red of the incandescent lamp, the yellow of gas and the kerosene lamp, and the green of the gas mantle lamp. Not until I pointed out how red the electric signs seem when the air is blue with fog or mist then his eyes began to perceive the fact. The green of the mantle lamp was revealed to him by a visit to an interior with red walls. The yellow of gas and kerosene is most apparent against dark-blue.

The development of color by contrast can easily be illustrated in an interior that has dark mahogany furniture with green upholstery and draperies. Put a red shade on the lamp and the mahogany becomes lighter in tone and less prominent, while the green fabrics become darker in tone and advance toward the eye. Put a green shade on the lamp, the reverse happens and you have to be careful not to stumble into the furniture.

What makes most Mission furniture so displeasing to persons of fine taste and culture is not so much that it is the negation of style, and lumbers up the house with its waste of wood, as that its dark colors accentuate the unwieldliness and necessitate an environment that it is impossible to light satisfactorily. Let who will cry aloud for darkness in decoration, the illuminating engineer should demand light colors.

The best that can be done in a room with dark walls and ceiling is to use small units generously distributed and enclosed in globes or crystals that are competent to break up the light and distribute it without mural assistance. To direct all the light to the floor,—although this does produce high photometric tests in the plane of illumination—is to apply to general illumination, principles that are properly applicable to local illumination only. And even in local illumination the light reflected from book or em-

broidery is much more agreeable if it has been subdued before reaching the object illuminated. The printed page that shines beneath the light reflected down from the white polished surface of a tin desk shade is not lighted efficiently, though invariably lighted too much. A smaller amount of light from an opal globe or frosted bulb is infinitely preferable.

Illuminating surfaces are a necessity in artificial lighting. They may glow by refracted light or shine by reflected light, but you can no more get along without them, than you can pull yourself up by your bootstraps. And the light eaten up by these surfaces is not wasted unless they are opaque or dark in color and exact too high a toll. If they reflected and refracted perfectly, walls and ceiling and floor would be solid mirrors reflecting and re-reflecting unshaded flames; this would be the extreme of economy, but it would not be decorative illumination.

The light that is eaten up by reflecting and refracting surfaces is not wasted. Its disappearance tones down the luminous whiteness, leaving the light that is not devoured fit to illuminate objects utilized as a reflecting surface.

DISCUSSION OF MR. HUNTER'S PAPER BY THE NEW YORK SECTION.

Mr. H. F. Huber.—The logical sequence of treating an interior with which illumination has so much to do, is to take into consideration the desires of the man who is creating the building, namely, the architect. It is the duty of a man who comes after the architect to embellish or complete the interior, to follow out the architect's ideas, and to attempt to increase and carry out the effects which it was the architect's intention to have carried out in the building.

Heretofore it has always seemed to me to be the idea that each one was going to show what he could do regardless of the other. That has been the means of creating a great deal of ill-feeling among the profession of architects and the trade of decorators. And so it has been with other branches of trade dealing with this subject, namely, the chandelier and electric fixtures manufacturers, who look for the opportunity of putting in as many lamps or fixtures as they can get into the building, to make their work sufficiently prominent so that any prospective customer coming

into the building will be more impressed with the fixtures than with the rooms which these fixtures are supposed to illuminate.

All the trades should work in unison. The illuminating engineer should be called in consultation by the architect and by every man who has any work to carry out in the building relating to form or color. Unfortunately the electrical engineer under the direction of the architect usually distributes a number of outlets, regardless of what the final treatment of the room is to be, and the result has not been satisfactory. The architect should consult the illuminating engineer or the man who is handling the illuminating work regarding the placing of the outlets and the manner of illuminating the building before the contracts of the building have been given out.

Dr. H. H. Seabrook.—There is a great deal of difference in colors according to the intensity of illumination. If on a black ground, a disc of red and green is placed, and this is illuminated by red light, the green, if it is greenish-blue will disappear and merge into the black, because the two are neutralized, forming the complementary color. If we reverse it, and use green light, the green becomes brighter, while the red is neutralized. If this is changd to a white background, then the principle of simultaneous contrast applies. Mr. Hunter has shown this in the paper beautifully as far as the actual results are concerned. The principle of simultaneous contrast rests upon the fact that the white surface receives the illumination from the color, whether through colored glass, or from the illuminant, and that color, by contrast, makes the central color appear paler. I should say that in using colored globes, we have the principle of simultaneous contrast, because of the white beneath.

The law of simultaneous contrast has been followed out in all its entirety mathematically with kerosene, ordinary gas burner, Welsbach, acetylene, and the incandescent lamps, tests having been made with colored letters upon a white ground. The demonstrations show a very peculiar state of affairs. Dr. Franz Becker remarks that there are many surprises, but the most surprising thing of all to me he does not mention in his paper on the effect of color. The strong blue, acetylene lamp, with its violet light in excess of daylight, and the kerosene lamp with its one-tenth of violet light rays, and its excess of red give the

best color contrast, and with the incandescent lamp and the gas lamp the contrasts are the poorest.

Regarding the question of the taste of artists, to which Mr. Hunter referred, we have many artists of recent years, of what are called the Impressionist School, who give us curious green and more recently purple effects, and form effects with dim outlines. Some oculists have shown that the Impressionist School of Artists are men with defective vision for form, and many of them are affected with partial color blindness, which leads them to exaggerate some colors in their pictures and suppress others.

There is a science back of this thing, and when the science becomes properly merged with the art, then of course we will have exactly what we want to perpetuate the art; but that merging must come from men like Mr. Hunter, men of taste, observation and real science, and they must formulate these things into what might be called mathematical and scientific consistency.

Mr. E. Y. Porter.—There is just one point upon which I would like to take issue with Mr. Hunter and that is in reference to the sentence where he says, "The light that blinds the eye at three feet is harmless at nine, having lost eight-ninths of its intensity." If by that is meant the source of light, I think it is an error, because the intensity upon any particular infinitesimal portion of the retina remains practically the same,—theoretically it does remain the same,—no matter at what distance the lamp is viewed. Of course, eventually the bright point of light becomes so very small that it affects so few of the optic nerves as to lose its effective glare, but roughly speaking the light from an incandescent lamp at three feet is no more intense on any particular part of the retina than it is at two or three times that distance.

Dr. Louis Bell.—It should be especially recognized that the colors on paper and on paints, with which the decorators have to deal, are two very different things. The colors in paints are much easier to deal with in the matter of illumination than the colors in papers, because the colors in paints show what might be technically called diffuse general selective reflection, whereas those in the colored papers, which are generally dyed with a so-called aniline color, are things which show the most eccentric

kind of selective reflection. Ordinary paints, therefore, change tones somewhat. Blues in papers almost universally show a lot of blue-green, which causes all kinds of disturbance when the lights begin to verge on blue or green. A good, pure, green paint or colored paper is pretty near an impossibility; the best greens, the purest greens that we get are blue-greens. Many of the brilliant greens found in some parts of the spectrum are never found in pigments at all. Green is always complicated with something else. Five greens out of six in papers have a very considerable red component, and in certain combinations of light that tone comes out strongly. One of the very best deep red screens for dark room use for photographers can be made by superimposing a deep red on a deep green, the resultant deep red band which is transmitted by the green is a very dark cherry red which will not affect the most sensitive plate. The yellow greens run into orange and up into the blue. Pure yellows, in a similar way, are extremely difficult to find—they run both ways, into the orange and yellow-green, over a wide range. All the yellowish oranges and pinkish shades found in papers are most complex combinations of colors.

Reds almost always include a lot of light orange and yellow and yellow-green, and also frequently quite a bit of violet. It is almost impossible to find any one dye put on paper or fabrics which does not let through two distinct elements of the spectrum, and consequently these colored papers and colored fabrics make the most extraordinary jumps in color tone, when the color of the light is considerably changed. Instead of merely darkening and changing tone a little they pass from one thing to the other with extraordinary violence, so that it would really be worth while for the decorator to put the spectroscope on all papers and see what colors they contain. Of two reds, greens or yellows, for example, which look to the eye almost precisely alike, one will hold its color fairly well under artificial light, and the other will pass off into something entirely different. With paints one can get comparatively constant and consistent results, but the eccentricity of the absorption in the dyes used in papers is a subject which merits a great deal of study from the standpoint of the decorator.

Mr. A. J. Marshall.—I should like to say a word in reference to the paragraph in which Mr. Hunter says: "Of the twenty-

six cases illustrated, the only one that shows an effective light distribution is the one with the bare lamp. In most of the other cases reflectors and refractors of various types have succeeded in taking the light from ceiling and upper walls that can distribute effectively, and in concentrating it on the floor where it is objectionable. I would not for a moment deny the value of prismatic shades and globes in many instances, especially where a room is too high and the plane of illumination really needs to be lowered, but often ignorance of the importance of walls and ceiling in light distribution leads to serious and expensive error."

It seems to me that in the main this paragraph is rather inconsistent, inasmuch as generally in a room used for living purposes it is essential to illuminate more brilliantly the lower portion than the upper side walls and ceiling. If one relies on the reflecting ability of the average covering used for walls and ceiling he will find it exceedingly expensive to obtain the desired amount of illumination in the lower portion of the room. It is absolutely necessary, however, that the upper portion of the room should not be in darkness, and this is just where the prismatic globe and reflector meets the demand, as it not only delivers to the plane to be illuminated the maximum rays of the light source, but also permits of a certain quantity of the rays emitted by the light source to penetrate its back, giving to the upper portions of the space sufficient rays to light it in keeping with the maximum thrown below the horizontal. It, therefore, seems to me that this type of globe and reflector accomplishes just what Mr. Hunter desires.

While the question of color in general is up, I should like to be permitted to say a word or two on a theory that I have as to the method now used in illustrating symbols in printing. At the present time by far the greatest percentage of all matter is printed by the use of black ink on white paper, which, to my mind, seems to be just the reverse of what we should have. In other words, it is my opinion that much better results could be obtained by the use of light tinted symbols on dark tinted paper. With the printing of today, we do not actually see the symbol, provided we can assume that the ink which is used absorbs all the light rays striking its face, but rather see the print by contrast. In other words we see the white paper and not the print. If we would use light tinted symbols on dark paper the symbols

then would reflect the light rays and we would therefore see directly. As an example, we may point to the blackboard on which generally white chalk is used, or the method generally employed in our street signs, where a blue background is used with white lettering.

Mr. G. L. Hunter.—While I did not bring out in my paper the point Mr. Marshall made about the refraction of the globes, I realize this as one of the most important and valuable features of the refracting reflectors and reflecting refractors. It was far from my intention to deny them value in the actual placing of light, which is to be derived by means of these refracting reflectors. I simply deplored their use where they are unnecessary.

I should like to speak of the law of inverse squares that has been criticized by Mr. Porter. Most of us are sufficiently familar with it to realize that, as the distance from the lamp increases, the light is distributed over area that varies as the square of the distance. The result is that less light enters the eye, varying in the inverse proportion. It is easy to test the matter practically by putting the naked eye within one inch of an incandescent lamp. See whether the glare is not more hurtful to the eye there than at ten feet away?

DISCUSSION OF MR. HUNTER'S PAPER BY THE CHICAGO SECTION.

Mr. F. J. Pearson.—I am particularly struck with the forcible way in which Mr. Hunter refers to the colors in nature, and especially to the illustration he uses regarding the rising and setting of the sun. I remember asking a prominent designer (one whose styles are very much sought after and who enjoys quite a reputation) the secret of her success and popularity. She said that her success was due to her faculty of being able to combine the colors of nature in her work. She was in the habit of studying the natural foliage and the colors at sunrise, and noting the colors at sunset. She believed this to be largely the secret of her success.

A few days ago I asked a prominent decorator to what he attributed his good work, that is, where he had a free hand to

do as he pleased. He believed his success lay in a close adherence to the color scheme prevalent in nature. He also said that unquestionably the treatment of light in illumination should always be on the basis of natural light, that is, the light from natural sources, both as respect to colors and general scheme. All of this leads me to believe, without having made any great study of the matter, that successful lighting as applied to decoration must take into consideration the colors of nature and the colors present during daylight.

The author has mentioned that it is a wise thing to avoid strong contrasts in colors. I think that is true in some respects. He says in a room where green is prevalent to avoid the use of red shades, and where red is prevalent to avoid the use of green shades. I certainly believe there would be some question among decorators as to the advisability of this. Where the prevailing color is green, almost invariably we will find a red shade. I don't feel competent to say whether he is right, but public opinion and general practice gives a line on some things which we must observe more or less.

Mr. George H. Jones.—The matter of having the color of shades exactly match the decorations of the room cannot be carried too far. When one buys an expensive lamp shade it is supposed to last many years, during which time the color of the wall decorations may frequently be changed. It is, therefore, desirable to have the shades of such a tint that they will harmonize with almost any of the ordinary color schemes which might be adopted.

Chairman J. R. Cravath.—As I am one of those referred to by Mr. Hunter as exerting some effort to illuminate interiors without "wasting" light on ceiling or walls, I am glad that Mr. Hunter brings up this point so prominently in his paper, that we may discuss it and come to a better understanding. To begin with, we should clearly understand what is meant by "wasting" light on ceilings and walls. My idea of waste is to give the ceilings and walls an illumination in excess of that required to bring them out properly and to produce the diffused lighting necessary for comfort. This certainly does not mean that the ceilings and walls are to be deprived of all illumination. The point that a great many of us in the illuminating engineering

field have been trying to make is that in the majority of cases more illumination has been expended on ceilings and walls than is necessary, and that therefore there is an undue waste of illumination which might better be expended in a plane where needed for use by the occupants of the room. I have observed in many cases that the relative percentage of illumination on the side walls and ceilings can be considerably reduced without impairing the general effect, and that in so doing we may recover for utilitarian and commercial purposes considerable light otherwise wasted by absorption and multiple reflection. It is not unnatural that Mr. Hunter should, as a decorator, look chiefly to the illumination of walls and ceilings rather than to the illumination of planes of the room where the occupants have particular need for it. In 99 out of 100 cases, however, where artificial light is used commercial economy is in some degree an object and the illumination of decorations on ceilings and side walls is of secondary consideration. At the present time it is generally true that walls and ceilings receive a larger proportion of the total illumination by artificial light at night than they do by natural light from the windows in the daytime. So far as bringing out a room as an example of the decorator's art is concerned, artificial illumination, therefore, offers greater opportunities than natural illumination. But that is no reason why the artificial lighting of the decorations should be overdone.

The diffuse reflection from walls and ceilings is a very pleasant and comfortable addition to the direct rays from a source of light in a room when it is received upon a reading page or on any object upon which our attention may be centered. As to how large a proportion of this total light should be received by diffuse reflection from walls and ceiling and how large a proportion direct from the lamp or its reflector is a matter which is worth careful consideration in any case. As Mr. Hunter has pointed out it is useless to depend on a dark wall or ceiling for much diffuse reflection. On the other hand, we may receive all our useful light by diffuse reflection from a light ceiling and none directly from the source. In the latter case we lose in efficiency, but the loss may in some cases be justified by the eye comfort.

Mr. Von Holst.—I am much impressed by the statement of Mr. Hunter in regard to avoiding contrasts not only in the color decoration, but also in the illumination. Take for instance this

particular room; to light it in day time there are windows in the walls. In this particular case there are two openings in the end wall and a very small proportion of openings in the long side wall. If we had only the glass between our eye and the outside light and no hangings in front of those openings the contrasts of the natural lighting in the daylight would be too great; there would be a dark wall and a light space of the window and again a dark wall. The hangings help to reduce that contrast and to blend the openings for the admission of light and the walls together. That same effect should be sought for in artificial lighting. The purpose for which the room is intended has a great deal to do with the general scheme of lighting. In the corridors and halls one would naturally want a more diffused lighting because when coming into a hall or corridor he desires to be able to see clearly the different doors and the stair case. In other words, the illumination should be of such a character as to avoid spots of light, and the light should be well diffused. Yellow is the most pleasing and cheerful color, and the light from artificial illuminants should be yellow and diffused so that the effect of a well lighted room is obtained. In a ball room where there is a great deal of ornamental plaster work, if there are too many spots of light the fixtures will throw shadows which were not intended by the architect or decorator.

A den or library should have just sufficient light to illuminate it. There should be a lamp at the seat, and possibly just a few clusters between the beams. In such a room one does not care for a brilliant illumination.

I wish to say a little regarding predominating colors. In decorating a room one should first settle on a general color scheme. If the scheme is blue, one should make that color a dominating one. This point is brought out in Mr. Hunter's paper very clearly in recommending cool colors in the north room and warm colors in the south room. If the panel work of a room is treated in red and lamps with green shades are installed, the two will fight, while if the shades are red they will suit the general color scheme very nicely.

EXTENSION OF GAS FOR ILLUMINATION.*

By G. W. Thomson.

At the various conventions of gas associations, also the meetings of the Illuminating Engineering Society, many papers have been read and discussed on the general subject of "Gas Lighting." These papers have covered the early history of both gas and gas fixtures, and as all of these papers are on record, it is not my purpose to go into that early history; but I do want to call your attention to the gas lighting of the present. Gas engineers and fixture manufacturers by their perseverance and enthusiasm have designed, built, and put on the market, gas fixtures with new principles that are most practicable in their application, and by the use of which a wonderful advance in gas lighting has been made.

One fixture manufacturer who is interested in the art of illumination, after being called upon a number of times to build efficient gas chandeliers, has designed some that have beauty, strength and symmetry, without sacrificing the proper illumination.

The cost of some of these fixtures has run as high as $1,000 or $1,100. By doing this special work, it assured him that there are people who prefer and will use gas for illumination. This, and many suggestions from the Illuminating Engineering Society, have been the means of his issuing two new gas fixture catalogues. One is confined to a higher class of chandeliers to be used in connection with the inverted gas burner; the other deals with especially designed chandeliers suitable for upright burners. The demand for lamps of small candle power has been met by high class brackets to be used in living or sitting rooms, and equipped with the Welsbach lamps of 20 candle power. This method of illuminating the sitting or living rooms has become very popular. It not only lends itself to attractive and artistic effects, but is much more efficient. They can be used as individual reading lamps, and save crowding around the library table.

Many artistic and elaborate installations of gas lighting have

* Read before the Philadelphia Section, February 21, 1908.

been made, and are being made, the effect of which is not only beautiful, but being applied on scientific lines, affords good illumination.

By being in contact with the buying public and architects we hope to demonstrate and prove to them that gas, with just enough tinge of yellow to make an agreeable appearance, and proper fixtures with which to supply this gas gives a satisfactory and good illumination.

With the introduction of the inverted gas burner, the possibilities of pleasing and decorative arrangement in the case of incandescent lamps have been enormously enhanced. The user of light has only himself to blame if he fails to get something attractive in the way of gas lamps; there is no lack of means to satisfy even the most fastidious taste in the world of modern gas lighting.

Great changes have been wrought during the past year in the lighting and extinguishing of gas lamps. They are now being lighted and extinguished from any one or more distant points throughout the building, by a simple and reliable device. The double push button, representing the stationary form of igniting and extinguishing, is located in the halls, entrances to rooms, etc. This form of lighting and extinguishing is also accomplished by a cord or pendant switch suspended from the fixture. It is a saver of gas, mantles and chimneys. Gas lamps in any number can also be lighted and extinguished by means of a double piping system; that is, the feed and pilot. I might say that great strides have been made with this system in the lighting of large halls, churches, signs, show windows, etc.

The "Jump-Spark System" and the "Straight-Spark Lighting System" have been and are used very extensively for long distance lighting. The jump-spark system of lighting, as applied to the inverted burner is a distinct improvement over the straight-spark used in connection with the upright burner. Long rows of inverted lamps are being lighted from one switch with or without the use of pilot lamps. By means of the automatic clock, gas lamps are being shut off at set hours. This is especially used on show window displays, there being many progressive merchants who allow their window lamps to burn until 11 o'clock or some set hour, when the clock automatically shuts the gas off.

By the use of a swivel joint, gas arcs are hung at the top of flag poles. This system also allows for the swinging of gas

arcs in foundry lighting, high sign or street illumination. With the swivel or union ball joint, the gas arms can be raised and lowered for cleaning or renewal of mantles, etc., similar to the mast arm used with the electric arc in street lighting. The illumination of machine shop or foundry floors is much more evenly distributed than by the old wall lamps or drop lamps above travelling cranes.

Combination chandeliers are now designed whereby the gas arms are being inverted and the electric arms are upright. The gas is provided for illumination, the electric for decoration. This is a step in the right direction, as the inverted lamp can be used with better effect and greater economy than the upright burner, as one-third of the light from upright burners is not thrown in the right direction. The fixtures are built along artistic lines and will certainly give gas lighting with combination chandeliers a very pronounced advantage over the former types. They increase the illumination and reduce the cost.

At the January meeting of the National Commercial Gas Association, a block chain stem inverted gas fixture was shown. The sample shown was a dining room fixture with art glass dome. This simple invention is a boon to gas lighting because it enables one to produce decorative effects for inverted burners, that to a certain extent are superior to the old devices for illuminating purposes.

The illumination of the sick room is a problem that should be carefully studied. There has been put on the market in London a new sick room gas lamp which not only gives very good illumination, but is used in the treatment of certain nervous diseases. The mantle is focussed in a silvered reflecting hood fitted with a handle so that the light can readily be accommodated to the face when the burner is suspended from a metallic tube. A sliding and jointed bracket and a balance weight are employed, which enable the lamp to be raised and lowered and moved from side to side. Another feature of the arrangement is the carrying of a pneumatic tube inside the flexible tube, thus enabling the patient to control the light from the bed; the by-pass acts as a very effective night lamp. One special advantage of the arrangement is that the nurse can have the light thrown upon a table while it is screened from the patient until it is actually required to facilitate the giving of food or medicine. This arrangement was devised for the particular purpose mentioned. It will be apparent that the contrivance will be particularly useful in any bed room,

especially for people who are fond of reading in bed. The sliding and jointed bracket combined with any form of inverted burner and shade should be appreciated for office or work shop use.

An inverted gas arc lamp of handsome design has been put on the market for the illumination of armories, halls, or most any large area. This lamp will certainly find a field which has not been filled by the upright lamp.

The operating and maintenance costs of present-day gas lamps have been reduced over the old method of lighting, and illumination increased. The writer has the optimistic opinion that the near future will show even greater possibilities of further advancement in the use of gas for illuminating purposes.

EYESIGHT AND ARTIFICIAL ILLUMINATION.*

By John T. Krall, M. D.

When a beam of sunlight falls into the eye, a sensation of "white light" results. The part of the retina acted upon is the layer of rods and cones. As to the transformation undergone by the ethereal vibrations in the rods and cones, various theories have been formed. The one most commonly accepted is the photo-chemical theory, which supposes that some chemical change produced in the rods and cones under the influence of light sets up impulses in them which ascend the optic nerve. This is the most profitable of all the theories, notwithstanding the fact that the discovery by Boll of the famous visual purple or rhodopsin, which at first seemed likely to place it upon a sure foundation, has, since the elaborate investigations of Kühne, lost much of its significance in this regard. It has disappointed the hopes that existed in sanguine minds, and has not explained, or even lessened, the mystery of vision.

In considering the question of artificial illumination it must be remembered, therefore, that as the action of light on the retina is photo-chemical, the danger from over-stimulation depends upon the photometrical sensitiveness which reaches its maximum in the yellow-green part of the spectrum. The red and violet ends of the spectrum are ineffective in vision, consequently must produce very little photo-chemical change in the retina. The danger of any source of light, therefore, lies not in the peculiarities of radiation, but rather in its excessive brilliancy. Over-stimulation depends on the concentration of the flow of energy in the image on the retina, which in turn depends upon the luminous radiation per unit of surface of the source. Kerosene lamps, candles, etc., never produce over-stimulation, as they possess only a few candle power per square inch, against some hundreds in arc and high efficiency incandescent lamps.

Many authorities on diseases of the eye would have us go back to the feeble candle, or the but slightly better kerosene lamp of our

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ancestors, because of that terrible bugaboo, ultra-violet ray, or X-ray, or some other obscure radiation.

Our streets, places of amusement, and even our homes are flooded with brilliant illumination to-day as compared to the darkness of our forefathers, consequently our eyes have become adapted to the brilliant illumination and brighter retinal images to such an extent that the dim light of candles and kerosene appears doubly so in comparison. This is clearly demonstrated when persons living in our large cities travel out into the country, far from the glare of intense lighting. The night is of inky blackness to them, and they cannot see surrounding objects nearly so closely as those accustomed to it. The eye must first become adapted to the low light stimulus, and as the problem of proper lighting applies mostly to the large centers where population is dense, the competition is so keen in all business, professional, student and social life, that the eyesight is forced to its utmost in the struggle for the survival of the fittest. Kerosene and candles may do well enough for those unaccustomed to bright light, but certainly cannot apply to those living in cities.

The importance of sufficient light is made manifest by any attempt to read in the twilight or in a dimly lighted room. The tendency is to hold the paper too near the eyes in order to secure a large retinal image, or possibly take advantage of the law that the illumination diminishes as the square of the distance. The strain upon the accommodation and convergence brought about by this abnormal near-point, soon causes undue congestion of the eyeball and surrounding tissues, and thus leads to increased interocular tension, and to myopia or near-sightedness. This turgescence of the ocular membrane is still further favored by the disturbance of the circulation and respiration brought about by the faulty position of the body which is also usually assumed when the book is held too near the face.

Steuben, E. D. (In Diss., Amsterdam, 1906) investigated what part the work at home can have on the origin of myopia, as the result of more or less faulty illumination. His investigations include 55 of the wealthy and 46 of the less opulent inhabitants of Amsterdam. The sources of light were electricity, gas and petroleum. The light strength was always determined photometrically. In 37.6 per cent. of the cases the illumination was insufficient, so he concludes that the results of the improved lighting of

the school during the day is in many cases annulled by the conditions at home.

The electric lamp is the best source of illumination, so far as eyesight is concerned, that is offered at the present day. It is condemned by many writers without just cause, in many instances simply because some one considered as authority conceived a dislike for it and advised against its use, and the next man writing upon the subject accepts the authority and passes it along without going to the trouble to find out for himself. There are some few people who require other forms of illumination in order to use their eyes with comfort, but such cases are, as a rule, pathological, hence cannot be considered here.

The electric lamp properly used is a perfectly harmless source of illumination. It is not the author's intention, however, to convey the impression that the light from the electric lamp does not contain wave lengths that may do very great injury under special conditions. They may be exceedingly dangerous, as illustrated in a case mentioned in "Cosmos" (Paris, Oct. 12, 1907). In making a hole in the shutter of a turret on board a cruiser, an electric arc was used to melt the hole. The following day everyone who had witnessed the operation, from the Captain down to the sailors, were either half-blinded or horribly burned. The officer who had directed the work had the skin of his face completely scorched and of a deep copper color. It gave off a serous liquid like that from a burn. Several sailors who were at some distance from the turret had their vision so affected that they were sent to the hospital, and it was feared that they might lose their sight.

The electric arc, rich in chemical rays, especially when it is formed between certain metals, may produce such results, hence the necessity of protection during exposure to a powerful arc or to a mercury-vapor lamp in quartz glass.

Birch-Hirschfeld, Leipsic (Archiv. f. Opthalmologie, LXVI., H. I., June, 1907), emphasizes the importance of combating recent promulgations in which it has been stated that the use of Roentgen and of radium rays "is without danger" by recording the anatomical findings of a second eye which has been subjected to the Roentgen ray in the course of the treatment of a carcinoma in the region of the outer commissure. Twelve hours before removing the eye it was subjected to an intense exposure to the rays. The important anatomic findings were as follows: In the cornea at sexual points, amidst normal surroundings, beneath the epithelium

and the anterior layers were small foci of connective tissue cells. At these points Bowman's membrane was destroyed. The blood vessels of intermediate caliber of the iris and ciliary body presented vacuolization of the intuna. The lens and vitreous were normal. The retina ganglion cells showed pronounced evidences of degeneration. The principal changes were destruction of the chromatin substance and vacuolization of the protoplasm. There was no evidence at any portion of the retina of inflammatory process, the pigmen epithelium and the chloroid presented no pathologic changes. The macula showed no sign of cystic degeneration and the optic nerve was free from atrophia or inflammatory changes. The author considers the changes noted as having been due to the Roentgen rays. Baermann and Linser were of the opinion that the epithelial changes depended upon a primary lesion of the vessel walls. The author believed them due to the X-ray, but the exact sequence of events is not yet established.

Selenkowsky also in experiments with rabbits has demonstrated the danger of excessive or careless use of these agents.

Ammann, E. (Correspondenz-Blatt für Schwerzer Aerzte 1 Aug., 1906) applied X-ray for sarcoma of the choroid, and post-mortem change showed the rays had evidently acted almost exclusively on the choroidal capillaries.

Cramer, E. (Klein. Monatsblat, f. Augenheilk, XLV., 2 p. 47). The author writing of the frequent occurrence of cataract among glass blowers concludes that it is due to continued exposure to chemical rays, particularly ultra-violet, from the admixture of chalk and clay in the glowing mass, and advises instead of red glass as a protection, a water-chamber, the fluid to be colored with fucsin to arrest the chemical rays.

Garten, S. (Graefer Arch, LXII., p. 1112), investigated the visual yellow of Kuehne and the possible variations in bleaching of visual purple by light of short and long wave lengths. It was found that a retina exposed to unvarying violet light appears darker if previously bleached with yellow; that there is an increase of absorption of extreme violet rays, and a diminution of that of red rays, after previous bleaching, and that the formation of visual yellow can be observed in the living eye of the bleak-fish and frog after exposure to sunlight.

Junius (Ophth. Klinik., June 16, 1906) on the effects of strong currents on the eye, says we must take into consideration voltage, resistance, direction and kind of current (continuous,

alternating or rotary) the duration of exposure, and lastly the individual susceptibility of the patient. In many cases it is difficult to decide whether the condition is due to action of the current or fright. Some lesion of the nervous system may follow the accident which may explain the eye symptoms. It may also cause blindness from changes in the cortical centers of vision.

Birch-Hirschfeld (Graefe's Arch., LXIII., p. 85), in studying the influence of light adaptation on structure of nerve-cells of the retina in the dove, found a diminution of chromatin in the ganglion cells of the retina, after sudden light adaptation. Intense artificial light is much more active in destroying chromatin than diffuse daylight. An accumulation of basiophilic coloring matter was found in the inner member of the cones, in the form of an intensely colored horizontal stripe.

Metley (Arch. d'Ophtal., 1, 04, p. 207) made a series of experiments on dogs and rabbits, keeping the light from an arc lamp directed upon one eye for a total of from 50 to 90 minutes, with frequent interruptions. The other eye served for control. With those retinas treated by the method of Nissl or Berthe he found no alterations either in pigment, ganglion cells, or layer of rods and cones. On the other hand, in those treated by the Marchi method, the optic nerves showed a breaking down of the myelin into dust-like droplets. With short exposure this change reached 6 mm. back of the papilla. With the longest exposure this alteration reached nearly to the chiasm. Whether these changes were due to the action of the light rays or to the chemical waves, or to both, could not be determined. With the interposition of a red glass during the exposure these changes did not occur. The red glass, however, cuts out both chemical rays and a part of the light rays; and so is not conclusive.

A practical deduction from the experiments would seem to be that red glasses would be of service to those working exposed to long or frequent looking at bright electric lamps, such as the arc.

E. Hertel, Jena, in experimenting with ultra-violet light, found it to be decidedly bacteriacidal, but does not penetrate deeply into the tissues, though in a long exposure it will kill bacterial through the entire thickness of the cornea. It does not act through the lens. The changes in the tissues so treated consist of a proliferation of the fixed tissue cells.

Birch-Hirschfeld found after removal of the lens that ultraviolet light caused a solution of the chromatic substance in the nerve cells of the retina, both the nuclea and the ganglion cells.

Hess, C. (Arch. f. Augenheilk., May, 1907) tried the effect of ultra-violet light as given by a uviol lamp, upon the lens, and found degenerative changes in the epithelium of lens capsule with proliferation of cells near the equator.

After exposure to powerful electric light there is little discomfort at first, after a while all objects appear red. Six or eight hours later the conjunction becomes red, swollen and inflamed; pain increases; there is a feeling of sand in the eyes; they smart and burn; gradually the symptoms abate in days or week, but the partial blindness persists much longer.

Enough has been said to prove that electric light, especially when rich in ultra-violet and X-rays, is capable of doing much harm, but only under special conditions such as do not prevail when electric lamps are used as a source of illumination. And even those who are exposed to such radiation can prevent injury by wearing properly colored glasses.

Motais (Bull. d'l'Acad. de Medecine de Paris, 1906, March 27), suggests the wearing of spectacles made of yellow glass for near work. Objects are seen clearer because of the lessening of chromatic aberration. In this he agrees with Javal. The six different shades of commercial yellow glass were examined by Tscherning and Sarazin by means of the spectroscope and photometer, and it was found that shades 2 and 6 completely absorb the chemically acting blue and ultra-violet rays, while the remaining rays of the spectrum are but little influenced. The light shades should be used in illumination with kerosene, gas, and the incandescent electric lamp, while the dark shades are preferable in acetylene or the electric arc lamp.

Yellow glass is particularly useful in photophobia from keratitis in sunlight. In diseases of the fundus, such as choroiditis, one obtains from blue glass only a reduction of the vision, with no protection against the injurious action of the chemically acting light rays, while with yellow glass the vision is not affected, and yet the eye is protected against the actions of these rays.

In selecting the proper lamp for inside use, home, lecture halls, schools, theatres, etc., effort should be made to obtain uniform illumination throughout the room by diffusion. Deep shadows in a room are very injurious to the sight, as the contrast

is too great upon looking from a brightly lighted page or table to the surrounding darkened room. Work should receive a trifle more light than the surrounding room.

The light should be produced with as little contamination of the air as possible, and there should be a minimum amount of heat produced. The light should be steady, and not subject to rapid deterioration. Neither should it be rich in the spectral rays that are irritating to the eye. The lamp should be properly shaded and all bright points guarded against. The arrangement of unshaded lamps in show-cases may attract attention, but they are abominable so far as the eyes are concerned.

Indirect lighting is very desirable, but it produces the physical effect of insufficient light, as well as a loss of about 65 per cent. in the amount of light. For large rooms, such as lecture halls and workshops, the arc lamp is the easiest on the eyes; that is, of course, when properly placed and shaded. The violet rays must be disposed of before colors show their true value, and this may be accomplished by the opal enclosing globe or by a suitable reflector coated with enamel having a high selective action for violet.

The Curtis Publishing Company has equipped the press room where the two-color work is done with inverted arc lamps. It is necessary for the men doing the work to match colors, the two most extensively used being yellow and blue, neither of which can be seen by the ordinary sources of artificial illumination such as the gas lamp with mantles, the incandescent lamp, etc. The difficulty is overcome by using the inverted arc with upper and lower reflector. The lower reflector is made to just cover the inner globe, and reflects the light received from the negative carbon to the ceiling reflector, which in turn serves to concentrate on the printed sheets on the board light of quality such as lends itself to the accurate matching of colors. There is no shadow cast by the reflected light. This form of lamp is well adapted where the elimination of sharp light contrasts is important, or where true color values are to be maintained.

The subject of school room illumination has not received the attention demanded, for it is here where the future myopes are most frequently produced. As usual, Philadelphia is behind in such matters, trusting to daylight, and in rooms requiring artificial illumination, the gas with mantles. Of course there are those who believe gas the best light for the purpose.

Schilling (Journ. Gasbeleuchtung und Wasserversorgung, 1905) says gas illumination is not only equal to electricity as regards clearness and even division of light, but superior in halls where moderate illumination is required.

The Boston School Committee appointed a committee of three oculists and two electricians to consider the artificial lighting of the public schools of Boston and their color schemes (School Document No. 14, 1907). Experiments were made with two methods; direct method, and combined method, depending partially on direct and partially on diffused method, chiefly confined to the latter. The lamps used were what is known as "high-efficiency" or low watt incandescent lamps. The most satisfactory results were obtained from nine 36-cp. 40-watt tungsten lamps, each equipped with a diffusing prismatic reflector. These shades are constructed of prismatic glass coated on the outer or inner surface with a white enamel. These lamps were arranged in three rows of three lamps, each running parallel to the rows of desks, arranged in order to throw the downward shadow from left to right on the pupil's desk. The illumination on top of the desks with the lamps 10 ft. 6 in. above the floor was approximately 2.5 candle feet at every desk. About the same results were obtained from 100-watt Gem lamps with the same shades.

The objections to the gas mantle of course are the rapid change in color from greenish-white when new to a greenish-yellow after using a short time. The rapid deterioration in candle power is shown by Lansingh (Progressive Age, Jan. 1, 1907, p. 4):

Initial	20.5 candles	per	cut.	ft.	per	hour.	
96 hours	18.00	"	"	"	"	"	"
555 "	15.6	"	"	"	"	"	"

The heat of the mantle must also be considered; it is so great that platinum wire melts when placed upon the surface of an ordinary Welsbach "C" mantle, while it will not melt when placed in the naked bunsen flame.

In conclusion it may be stated that greater care should be exercised in securing a proper illumination by making photometric tests when possible, or by the use of reading type selected to correspond to different photometric calculations.

DISCUSSION OF DR. KRALL'S PAPER BY THE PHILADELPHIA SECTION.

Mr. Whitaker. The author called attention to the excessive temperature reached by the incandescent burner and stated that this is sufficient to fuse a platinum wire. However, the fact is that for severalyears the Welsbach Company turned out millions of incandescent mantles tied with platinum wire and is now using for this same purpose asbestos cord, yet there has not been a case where either the platinum wire or the asbestos cord was disintegrated by fusion.

The flame conditions in an incandescent burner (gas burner) and in an open laboratory bunsen are practically identical, and in view of the fact that a fixed amount of heat will be obtained from the combustion of a certain amount of the same gas under like conditions, it is very difficult to see how an incandescent burner flame can be made to develop a greater temperature than can be developed in an open bunsen burner.

It is also rather difficult to understand how an incandescent mantle burner consuming 4 cu. ft. of gas per hour would develop a higher temperature than an open bunsen tube consuming 6 or 7 cu. ft. when the conditions of burning are almost identical.

The rapid and peculiar deterioration of the mantle has been cited by the author as a disadvantage in the use of incandescent gas lamps. There is nothing to conceal in the matter of deterioration. It is a well known fact that the Welsbach mantle deteriorates in light during the course of 1,000 hours from 100 candles to in the neighborhood of 75 or 80 candles. While the percentage of deterioration shows up rather large, it should be noted that the high candle power of the unit left at the end of the seasoning period is yet quite sufficient to meet the ordinary demands.

The fugitive color of the Welsbach lamp has been urged as an objection, and I think it was cited that at first this color was a purplish white which afterwards changed into shades of yellow. This statement is contrary to the experience of the users of Welsbach mantles.

It is a well known fact that the color of the light given by the Welsbach is determined by the amount of active cerium in the mantle, ranging in the bluish white mantles from a few tenths of 1 per cent. to as high as 2 or 2½ per cent. in the very yellow mantles. Experience has shown that in use the cerium in the

Welsbach mantles becomes, from one cause or another, inactive, and its color changes in the exact proportion to the conversion of the cerium. It would follow, therefore, in view of these facts, that a normal mantle would give at the beginning a yellowish light which under certain circumstances would gradually turn to a white.

While the variable color criticism is lodged rather freely against incandescent mantles in general, it applies as a matter of fact only to the cheaper and more flimsy grade of mantles, and is directly due to the light texture and sparing quantity of material used. Where mantles are properly made and contain the proper percentage of cerium and thorium to meet the candle power and physical life requirements to the best advantage, the change of light is almost imperceptible, and is not recognized as a valid argument against this system of illumination.

Another point bearing on the injurious effects of the Welsbach system of lighting on the eye might be cited in connection with the experience in the factory where these mantles are made. Over 1,000 people are employed in this work, and a large percentage of these operators are engaged in hardening the mantle where it is brought to a state of incandescence far in excess of that developed in ordinary practice. It is impossible to protect the eye from the light developed in this operation, and the question has often arisen in my mind as to whether or not injurious effects result from continued work in these departments. I have yet to find an employe with eye trouble attributable to this cause. I have taken special pains to inquire into this matter, and the operators state that the work is not as hard on the eye as that in some of the other departments; for example, the knitting and sewing departments.

Mr. W. C. L. Eglin. The question of intensity of illumination, the heating value and chemical value, as far as the effect on the eye are concerned, are matters that must be considered by the illuminating engineer. The factors of candles, kerosene, gas, etc., are merely subsidiary to the question of the eye itself, and I feel that the suggestion of appointing a commission to prepare specifications for the lighting of school rooms is an important one and should receive consideration from all cities. The question of illumination is one of education, and we ought to begin by educating the children, and I understand that in some

foreign countries there is a clause in the school specifications requiring a certain window area for each cubic foot of room space.

Mr. W. H. Gartley. Owing to the preversity of children, it is very difficult to give them good light, as their tendency is to ignore all efforts at providing them with a room beautifully and scientifically lighted, and to upset all our theories. They will manipulate their papers and books in such a way as to get between the light and their work, and place their bodies in such shapes as to throw shadows and set up conditions that will nullify any attempt to give them the light they should have.

Dr. Krall. Authorities on diseases of the eye condemn the electric lamp and gas mantles as being injurious to the eyesight, and insist upon using candles and kerosene lamps which are unsuited to present-day needs in every way, without any justification whatever. As pointed out, kerosene frequently produces insufficient light which in turn acts as a predisposing factor in the causation of myopia, or near-sightedness, Furthermore, our eyes have become accustomed to light of greater brilliancy, and to insist that we return to a source of illumination sufficiently brilliant for our forefathers, but not for us, may show great reverence for antiquity, but very little consideration for present-day requirements. The burden of proof that electric lighting is harmful to the eyesight rests upon its objectors, and they have not produced the evidence. The heat of the kerosene lamp also is objectionable as tending to produce congestion of the eyeball and its appendages. It adds greatly to the vitiation of the atmosphere in closed rooms, in fact it possesses all of the undesirable qualities of artificial illumination, with few of the good. The objections of gas are, as previously stated, the rapid deterioration, change in color and great heat.

In answer to the query why it is that a gas mantle flame will melt a platinum wire when an open bunsen will not, I must state that the phenomenon is out of my line. Weber (Prog. Age, Mar. 1, 1907, p. 140) suggests that it may be due either to the catalytic action of the mantle, or to mechanical effect of the meshes of the mantle in completing the mixture of air and gas.

The electric light is condemned as being injurious because of the ultra-violet and X-ray. As a matter of fact sunlight is as rich in ultra-violet rays as the light from the ordinary arc lamp.

when used for purposes of illumination, and the ordinary incandescent lamp as used in our houses is perfectly harmless as far as injurious rays are concerned. It should be remembered the various rays producing the harmful effects on the eye quoted in the paper, were procured from electricity under special conditions, and not when used as a source of illumination. The only danger from the electric lamp is of too great brilliancy, which can be controlled by proper shading. All the ocular symptoms complained of by those using the electric lamp can be cured by wearing the proper glasses to correct defects in their eyesight, and by using the proper amount of illumination.

DAYLIGHT ILLUMINATION.*

By L. W. Marsh.

It has long been known that the light reaching a room is decreased by reason of the proximity of buildings, trees or other natural objects. The fact that the illumination of such a room can be rendered satisfactory by the use of prismatic light-diffusing glass seems, however, not to have been considered seriously until about eleven years ago, when a certain inventor succeeded in interesting a group of Chicago business men in this idea. These men organized the American Luxfer Prism Company, which employed a force of physicists in designing new forms of glass prisms under the direction of Dr. Henry Crew of Northwestern University as consulting engineer.

The researches of these physicists led to the production of the so-called "Luxfer" prisms, which consist of sections of clear crystal glass having a smooth outer surface and a series of accurately formed prisms on the inside. These units are glazed into plates similar to leaded glass. These plates are placed in or near the window openings and by means of the prism section on the back of the glass the light in passing through the plate is refracted in a given direction within the room.

First let us consider a simple case of a poorly lighted store on a fairly wide street. If the building across the street from the store is 45 feet high and is 35 feet distant and the distance from the bottom of the transom bar across the plate glass store front is 10 feet from the ground, it will be seen that the angle of incident light on this store front varies from the vertical light to light striking the plate glass at an angle of 45 degrees. Thus it will be seen that the direct light from the sky in passing through the store front cannot pass into the store farther than the point at which the incident light strikes the floor. Thus if the ceiling height is 15 feet, light will strike the floor only 15 feet back from the wndow. This will of course make very deficient illumination in the store. By means of Luxfers, the light which strikes the floor in the first 15 feet is directed from the horizontal down

* A paper read before the New England Section, February 18, 1908.

to an angle of approximately 45 degrees below the horizontal. This redistributes the light to the extreme rear of the store and the space near the window which has been robbed of light must either depend upon the lower portion of the window for its illumination or different angles of prisms may be installed in the upper plate to throw a portion of light into this space.

This redistribution of light will oftentimes increase the light in the rear of a room 60 feet deep by from 1,000 to 1,500 per cent., though it must be understood that the total flux of light in the room is not increased thereby. This applies for propositions where Luxfers are installed in a vertical sash.

In applying the proper angle of prism the room in question must be carefully examined as to decoration, architectural peculiarities and use to which the room is to be put, whether for storage purposes, heavy merchandise, fine merchandise or desk work. The windows must be carefully examined as to the extent of reveal, etc. The amount of skylight available for lighting purposes must be carefully measured. And after carefully considering the requirements, a form of prism must be prescribed which will not only throw light to the extreme rear of the store, but will also diffuse it to right or to left, or direct it to the ceiling if for some purpose it is so required. The recommended form must lend itself to the architectural features of the building, if possible, and be as unobtrusive as possible.

The varying conditions of sky make it necessary for the company to have over 100 different angles and forms of prisms to be able to properly treat the various problems that may arise.

The amount of light required for fine merchandising, such as dry goods, jewelry, etc., is a certain definite quantity, but the standard by which this light is compared cannot be definitely designated. To express it in foot candles might be possible, but under the varying conditions of general illumination it would be a very difficult matter to determine the exact illumination by any pre-arranged system of mathematical calculation. Suppose the store under test is a high grade dry goods store. The disposition of goods makes a great difference in amount of total effective illumination. Goods are often displayed in vertical racks either suspended from the ceiling or perhaps hung out from the shelf ledge back of the counter. This arrangement may entirely destroy all effective light which may be directed properly down through the store; the light strikes the first display rack and throws

the counter and goods beyond in a disagreeable shadow. This same effect is noticed in providing artificial illumination. The condition of light and shade caused by the improper display of goods is often a very serious handicap to the engineer who is trying properly to solve the problem. The question also of diffusion from different displays of goods may be carefully studied and the effect noticed, and in many cases goods may be placed at certain locations to assist in lighting a dark corner. The question of diffusion of light from the ceiling also is a feature. A heavy beamed ceiling with deep panels cannot be depended upon to increase the daylight illumination. The heavy shadows cast by the beams upon the panels make the ceiling of very little value as a diffusing surface. If, however, the ceiling is smooth and unobstructed by beams or ornamental panels, it may be used to very good advantage in increasing the total illumination in the room. This, of course, applies to the ceiling surface close up to the windows. The illumination on the ceiling caused by direct light from the window opening, of course, will not be very strong at any considerable distance from the window due to the small angle at which the incident light strikes the surface.

The texture of the surface also affects the diffusion, as does also the color of the surface. Thus it will be seen that in the lighting of an ordinary dry goods or any store where goods are displayed there are a great many factors entering into the final equation, and very often these factors are variables to which no definite fixed values may be assigned. The constantly changing display of goods makes a corresponding change in the resultant diffusion therefrom and in the total illumination.

The effect of color of walls has been treated in a superficial way by the Luxfer Prism Company. A large room approximately 25 feet long by 20 feet wide with four windows with two windows on adjacent sides was used for test purposes. Opaque shades were fitted at the windows so that the light could be admitted from the end or the side of the room. A fixed flicker photometer was arranged in the corner diagonally opposite the corner between the sides in which windows were located. This corner being farthest from the windows it was considered that the varying illumination at this point would give data which would be more or less of value and of considerable interest. Curtain rollers were arranged at the top of the four walls, and upon

these rollers were hung curtains of colored cheese cloth. These curtains could be operated quickly, and by comparing the illumination caused by light from one set of windows with walls whitewashed with the same set of windows with walls of any chosen color, a definite factor might be obtained for that particular condition. By changing the location of the light source and having the same change in color of walls, another factor was obtained. While this might be exact for the chosen conditions, it would not be accurate to take an average of the two factors and say that this was the absolute factor of loss in illumination due to the introduction of the new color. It was, however, very interesting to note these results. In a general way, the diffusion factors thus obtained approximated the exact diffusion constants which had previously been obtained for light diffused directly from various colors of wall paper, by using the method described by Sumpner in the *Philosophical Magazine,* February, 1893, and reproduced by Basquin in *Ill. Engr.,* August, 1907.

By means of color cards which were gotten up by the company it is possible to approximate very closely the amount of diffusion due to the different colored wall coverings. This must, of course, be approximate only, but it is an aid in making recommendation for improved illumination.

The amount of illumination required to do a certain work without tiring of the eyes may be assumed as a standard for that particular work. Individual opinions may vary as to the amount of light required, but by making a careful survey of a large number of stores of similar character, the average of the desired illumination may be noted and in a general way classified. It would seem that four classes of light would suit the wide range of diversified requirements. These classes may be arranged as follows: Class A—Light sufficient for storage purposes. In this light boxes and merchandise may be piled up and distinguished readily by general outline. The light not being sufficient for reading labels or other printed matter except in very large type. Class B—General merchandise. In this class would come heavy hardware, machinery, furniture and other large articles where a good light is required—a light sufficient to read labels on ends of stock drawers, etc., with comparative ease. Class C—Fine merchandise. Dry goods may be sold under this class. A fine quality of light is required for this grade and an abundance of light must be had in all parts of the room. The light must be

sufficient to enable one to detect flaws in the finest textures and to readily distinguish colors in their true values. Class D—Desk work. This is, of course, the highest requirement. In this class the light must be such that no artificial light will be required at any time.

In taking up these classes of light and the requirements for their existence, consider first the requirements for desk light. The illumination desired may be impossible of attainment. Thus with a small window and a high obstructing building opposite, the total amount of light entering the room may be entirely inadequate and even by the installation of a properly designed prism the total flux of light will be sufficient to light a space limited to a very few feet from the window. By observation of a vast number of offices where the light is good and bad with varying amounts of available skylight, one may determine with fair accuracy the exact window area which may be required to give the illumination desired. It is, however, always necessary to note the distance at which the light is desired from the light source, and the angle of incidence. If the highest light falls on the desk at an angle of more than 60 degrees with the normal, it will take an immense amount of light and glass area to produce a satisfactory illumination. Unfortunately the daylight engineer is not usually consulted until after the window openings have been fixed, and in many cases the interior fittings have been arranged so that there is little chance for changing the light in an adequate or wholly satisfactory manner. It is usually a problem of equipping the windows with properly adapted spectacles and make the best of a bad proposition.

A new building presents a different problem, which may be solved in a thoroughly satisfactory manner by making the light sources large enough to carry the available light to the points where most needed, and to arrange for desks at the most advantageous points. It is rarely possible to place desks more than 30 feet from the window unless the ceiling is exceptionally high,—sixteen feet or more. This limit has been adopted by the standard authorities on school house construction. The greatest depth of room used for study purposes is about 32 feet.

It is possible by means of prism glass to obtain sufficient light at 32 feet from the windows, even though the light in the room under ordinary conditions requires artificial light constantly. The

light may be restricted by an opposite building so that the incident light on the window may make an angle of 70 degrees with the normal, and by means of a canopy or awning of properly designed prisms sufficient quantity of light may be directed 30 feet from windows and give an entirely satisfactory result. It is, of course, necessary to make large window openings and large canopies under the above conditions, but it is possible to obtain satisfactory desk lighting under these extreme conditions.

For fine merchandise the area of window opening may be made somewhat smaller, and the diffused daylight will be good at a distance of from 50 to 75 feet from the windows, and fine goods may be shown in the middle of an ordinarily dark room. No ordinary salesroom 100 feet deep with the customary plate glass windows covering the entire end of the store, which has to depend solely upon the light received from this source can be satisfactorily lighted throughout the entire area by means of the windows alone. The prism has become as necessary an adjunct to the proper illumination of stores in daylight hours as has the electric light by night.

Between the fine merchandise class and the general merchandise class there is only a slight difference, but the difference may be noted in the lesser area of prism glass required to satisfy the requirements for general merchandise. For storage purposes about one-half the area of prism glass will be required as is needed for fine merchandise, under the same conditions of skylight.

In making the first tests for forming tables of glass areas required, the exact amounts of skylight available are very carefully computed, and the proper angle of prism is specified, and after the installation is complete, the illumination is carefully judged by competent observers. It was at one time thought advisable to test the illumination before and after by an illuminometer based on visual acuity principle. An illuminometer was made by using disks of different density, varying in geometrical progression, on a circular photographic plate. The illumination was produced on a sheet of rice paper back of which was a piece of clear glass upon which an image of a cross was painted. This was viewed through the disks of varying density until the cross showed with equal distinctness as compared to the appearance under a previous illumination of different intensity. Several installations were made under a guarantee of a definite percentage

of increase in light by means of the prism glass and the result was tested by this illuminometer. The instrument proved quite convenient, but it possessed defects not desirable in an accurate scientific instrument.

There has recently been devised a portable flicker photometer which will greatly simplify the labor of testing illumination in any part of a room. By the use of this instrument the illumination at any point may be measured and the entire hemisphere of light above the plane of observing screen may be unobstructed, and the exact values may be obtained in definite terms so that daylight illumination may be compared favorably with artificial illumination. The flicker principle will enable one to compare lights of different colors with greater accuracy than by the use of any other photometer with which the writer is familiar.

The forms of prism glass which are most commonly seen in use are the plates installed directly in the upper window sashes of a store front and the canopy or awning form projecting over the windows. These are, however, only two of a great many forms. Luxfer prisms for "skylights," "floor lights," "ceiling lights" and "sidewalk lights" have their respective forms, and the many different and peculiar installations would prove very interesting to observe. In this limited paper only one or two of the most unusual can be treated.

Recently a rather unusual problem was presented for solution. A church window in exquisite coloring in leaded stained glass was found to be very poorly lighted and the colors appeared dead and lifeless. It was apparent that the defect in color was caused by defective illumination as the result of a shadow caused by a chapel roof which was only a short distance away and which limited the incident light on the window to an angle of 37 degrees from the vertical. There was, of course, only a very limited amount of light, and even had the window been of plate glass at least 30 per cent. of the light would have been lost by reflection. The amount of effective light transmitted through the stained glass was limited to a very small range of observation, and as the window was at one side of the chancel and quite high above the floor, the colors in the window could be seen in their true values from only a small space limited to the chancel itself. In the body of the church the window appeared dead and lifeless due to the dark slate roof which showed directly behind the window. Another disadvantage appeared in the fact that the window

was in a side wall and the apparent area of the window from the body of the church was very small.

On the left and directly opposite this window was the high roof and this roof ended on a line with the right side of the window. To the right beyond this end of the opposite building was an open area of sky, the central axis of which was about 15 degrees to the right of the window and the zenith angle of which was about 50 degrees. Thus the light at the left of the window inside of the church was very good, while to the right inside the light was bad on account of the slate roof. The problem at hand was to make the effective illumination over the entire window uniform and at the same time obtain a new direction for the intense light. It was accomplished in the following manner: An iron frame was erected outside the window at a distance of 15 inches from the stained glass. This frame covered the entire window. In this frame were placed plates of Luxfer prisms which took the light from the sky at the right of the window and changed its course in both a vertical and a horizontal direction and turned the emergent light from the prisms to a more effective angle of incidence on the stained glass window, and at the same time directed it toward the main auditorium.

The angle of incidence of the rays through the prisms upon the window averaged 20 degrees with the normal, while under the previous conditions the angle of incidence was nearer 70 degrees. The visual effect was satisfactory, and the colors in the window appeared uniform from the top to the bottom of the plate, and the design of the window could be more clearly seen from the main auditorium.

A problem of this kind must be very carefully studied, and in the perscription of angles required a perfect knowledge of various peculiarities of each prism must be had. In the problem referred to five different angles were used to obtain the uniform illumination desired.

In discussing the matter of daylight illumination it is difficult for the writer to consider it from a disinterested standpoint; that is, other than in some connection with the Luxfer prism proposition. For to the writer's knowledge there has been no attempt at improving interior daylight illumination other than by the Luxfer method which has been at all satisfactory.

The only other method of reflecting daylight with which the writer is familiar involves the use of mirrors. This method had

been used for a great many years, but the disadvantages of the required form of construction and the limited diffusion of light obtained therefrom have precluded its very general use.

The light of a room may be deficient both in quantity and quality. There is no known way of obtaining a direct diffusion of light through an opening such that the light will be directed to the extreme rear of a dark room except by prisms. It would be just as foolish to consult an ordinary window glass dealer in a matter of this kind as it would be if you desired a properly fitted pair of eye glasses. There is not to the writer's knowledge a plate glass house in the country which employs an engineer who can make a proper measurement of sky area and determine the proper prescription of angles required to obtain a desired result.

An illuminating engineer could recommend proper prisms for daylight illumination and he could solve the problem with entire satisfaction, but he would be at the mercy of the prism company and in most cases have to accept one of two or three angles and finally adopt a makeshift installation after a careful analysis and recommendation.

It is impossible to obtain in the open market prisms of any desired angle. An illuminating engineer might analyze a certain problem and find that to obtain the desired result a vertical prism having a lower angle of 45 degrees and an upper angle of 75 degrees (all measured with the vertical) would be required. Upon inquiry it would be found impossible to obtain this without making molds, etc., and all the attendant expense.

It is best for the illuminating engineer to consult with a concern whose engineers have a thorough knowledge of the matter of sky analysis and the relative merits of each form of prismatic glass. With the help of such a concern an illuminating engineer can make recommendations and know all the possibilities.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. APRIL, 1908. No. 4

At a meeting of the Council held on Friday, April 10, ten members who were elected prior to 1908, and had failed to reply to letters addressed to them by the Secretary requesting payment of dues, were dropped from the roll of membership.

A resolution of the Board of Managers of the Philadelphia Section relative to the proposed election of associate members of that Section was laid before the Council. It was moved, and duly carried, that the matter of this resolution be referred to the Committee on Constitution and By-Laws.

The Council was asked to consider the advisability of publishing in the *Transactions* the 1907 annual reports of the Boards of Managers of the several Sections. It was decided to request the Chairman of the Committee on Editing and Publications to abstract the reports, and to publish such abstracts in the *Transactions.*

It was moved, and duly carried, that the Committee on Nomenclature and Standards be requested to report to the Council at the next meeting its action in the matter of the report of the Sub-Committee appointed to consider a standard of light.

In acceptance of the report of a special committee appointed to nominate a Director of the Society, to succeed Mr. W. D'A. Ryan, Mr. John Campbell was elected to fill the vacancy in the Board of Directors.

President Bell appointed the following members to compose the 1908 Committee on Papers:

Mr. W. D. Weaver, Chairman, New York.

Mr. C. O. Bond, Philadelphia.

Mr. J. R. Cravath, Chicago.

Dr. Edw. P. Hyde, Washington, D. C.

Mr. S. G. Rhodes, New York.

The names of the following thirty men were approved for entry on the Membership Roll:

BASHAM, ROBERT B., Contract Agent, Western Dist., North Shore Elec. Co., Oak Park, Ill.

BYRNE, THOMAS W., Electrical Contractor and Engineer, 81 Mt. Pleasant Ave., Boston, Mass.

CASTOR, HORACE W., Architect, Asso. with Stearns & Castor, 1107 Stephen Girard Bldg., Philadelphia, Pa.

DENNIS, CHARLES W., Solicitor North Shore Elec. Co., Waukegan, Ill.

DOANE, G. W., President Amsterdam Gas Co., 23d St. and Lexington Ave., New York.

FAURE, JOHN P., Electrical Contractor, Asso. with Faure Elec. Works, Inc., Ossining, N. Y.

FELDMAN, A. M., Consulting Engineer, 120 Liberty St., New York.

FERGUSON, JOHN W., Asst. to General Contract Agent, Commonwealth Edison Co., 139 Adams St., Chicago, Ill.

FISHER, MORANGE SCHUYLER, University Heights, New York, Asso. with Electrical Testing Laboratories, New York.

HANKS, MARSHALL W., 1220 Michigan Ave., Chicago, Ill.

HESS, ROBERT M., Solicitor, North Shore Elec. Co., Wilmette, Ill.

HIETT, RALPH WALDO, Illuminating Engineer, Asso. with F. Bissell Co., Toledo, Ohio.

HOGUE, OLIVER, Chief Clerk, Contract Dept., Commonwealth Edison Co., 139 Adams St., Chicago, Ill.

HYATT, O. L., Dist. Superintendent, North Shore Elec. Co., Chicago Heights, Ill.

KELEHER, A. H., Holophane Co., 227 Fulton St., New York.

KERFORD, WILLIAM K., Foreman of Inspection Dept., Philadelphia Elec. Co., 1000 Chestnut St., Philadelphia, Pa.

KIRSCHBERG, Asso. with Pennsylvania Railroad Co., Altoona, Pa.

LAW, CLARENCE L., Special Inspector, New York Edison Co., New York.

LITTLE, W. F., Electrical Engineer, Asso. with H. W. Johns-Manville Co., 25 Fulton St., Brooklyn, N. Y.

MCBRIDE, THOS. J., Jr., Meter Tester, Mount Vernon Lighting Co., Mount Vernon, N. Y.

NORTON, W. F., Supt. Gas Dept., Nashua Light, Heat and Power Co., Nashua, N. H.

O'DONOVAN, L. J., Contracting Engineer, Asso. with Reis & O'Donovan, Inc., 1123 Broadway, New York.

ROCAP, CHARLES E., Treasurer, Electrical Construction and Supply Co., 237 Broadway, New York.

SCHUETTGE, EDWARD G., Asst. Superintendent, North Shore Elec. Co., Evanston, Ill.

SOLON, JOHN M., Solicitor, North Shore Elec. Co., Waukegan, Ill.

STEPHENS, L. C., Agent, North Shore Elec. Co., Park Ridge, Ill.

STRASSER, J. M., Supt., North Shore Elec. Co., Oak Park, Ill.

WARD, W. E., Electrical Contractor, Asso. with McLeod, Ward & Co., 27 Thames St., New York.

WENDT, SAMUEL J., Inspector, North Shore Elec. Co., Waukegan, Ill.

WHITE, MANNING, Lighting Solicitor, Savannah Lighting Co., Savannah, Ga.

NEW YORK SECTION.

At the meeting of the New York Section held Thursday, April 9, Dr. Clayton H. Sharp, past president of the Society, delivered a lecture on "New Types of Electric Lamps." All new types of filament lamps which have passed the experimental stage and are available in some quantities were discussed. The various processes by which tungsten is purified and prepared for use as lamp filaments were treated in some detail. Lantern slides were shown, giving the performance of various types of metal filament lamps; and a very complete exhibition of lamps completed the evening's program.

PHILADELPHIA SECTION.

The April meeting of the Philadelphia Section was held in the Assembly Room of the Philadelphia Electric Company, on Friday, April 24. The following papers being presented:

"Church Lighting," by Mr. Emile G. Perrot, architect and consulting engineer, member of the firm of Ballinger & Perrot, Philadelphia, and "Application of New Types of Electric Lamps," by Mr. W. A. Evans, an illuminating engineer of the Philadelphia Electric Company. Both papers were illustrated by practical demonstrations and lantern slides.

NEW ENGLAND SECTION.

The April meeting of the Section was held on Tuesday, the 14th. Chairman J. S. Codman called upon Mr. A. T. Holbrook of the Nernst Lamp Company to discuss a layout of a shoe store,

which was presented for general discussion, when lighted with Nernst lamps. He next called upon Mr. H. M. Daggett to discuss the same store when fitted with gas lamps. Mr. H. V. Allen was then asked to present a layout for the same store fitted with enclosed incandescent lamps. A general discussion of the subject followed. There were 39 persons present.

CHICAGO SECTION.

At a meeting of the Chicago Section held on April 9 Mr. J. J. Sorber presented a paper entitled "Relation of Direction of Light to Human Construction." The paper was discussed by Messrs. Bohnam, Keech, Hiett, Chairman Cravath and the author. Secretary Jones announced that 13 new members had been added to the Section roll since the first of the year.

REPORTS OF THE 1907 BOARDS OF MANAGERS OF THE SECTIONS.

CHICAGO SECTION.

The Board of Managers held a meeting each month about two weeks in advance of the meeting of the Section in order to make plans for the next meeting as well as for future meetings. Since the membership of the Chicago Section is composed largely of men connected with construction, design and selling, rather than manufacturing, testing and laboratory work, the aim of the managers has constantly been to have the program such as would appeal to this class of membership. The following is a list of subjects of meetings for the Section during 1907:

"Street Lighting." Topical discussion. Joint meeting with Northwestern Electrical Association, January, 1907.

"Residence Fixtures and Lighting." Discussion led by R. C. Spencer, architect, Chicago, February, 1907.

Discussion of papers by Messrs. E. A. Norman and Charles N. Cohn, March, 1907.

Exhibition and explanation of various forms of portable photometers for measuring illumination, and a paper by T. B. Lambert on "A Method of Photometry for High Candle-Power Units," April, 1907.

"Industrial Plant Illumination." Original paper by Mr. Geo. C. Keech, of the Chicago Section, May, 1907.

"Railway Car Lighting." Original paper by Mr. Geo. C. Keech, June, 1907.

"The Lighting of a Large Retail Store." Original paper by Mr. Frederick J. Pearson, October, 1907.

Discussion of paper on "Fixture Design from the Standpoint of the Illuminating Engineer," by Lansingh and Heck, November, 1907.

Topical Discussion on "The Lighting of Down-Town Streets," December, 1907.

The Section has followed the custom of meeting for dinner at some down-town restaurant immediately after business hours and proceeding to discussion immediately after dinner. In some cases adjournment has been made to the meeting room of the Commonwealth Edison Company, which has been used without expense in order to secure the use of a stereopticon or to obtain a room better adapted for the delivery of a paper. The committee on new membership did good work during the latter part of the year. The most effective work of this committee was in the way of personal solicitation among friends for new members. The membership has been constantly increasing at a healthy rate, and although the Chicago membership is not large as compared with that of other Sections, it is believed to be of a substantial character which is not likely to be lost. The percentage dropped for non-payment of dues has been low. The efforts of the management to interest architects and gas men in the Society have not been as successful as could be desired. This has been a matter of considerable concern and discussion. Recently gas men have shown more indication of taking an interest in Society affairs, but there is still much room for development.

Chicago Section expenses on a per-member basis have been high, due largely to the stenographic expenses of reporting discussions rather than to any extravagance in management. To reduce expenses by getting no stenographic report would, of course, be easy and perfectly acceptable to members of the Chicago Section who attend the meetings. This expense should, therefore, be considered not so much as one chargeable to any particular Section, but rather as an expense in publishing the *Transactions* for the benefit of other Sections and the membership at large.

PHILADELPHIA SECTION.

Since its election on February 15, the 1907 Board of Managers has not had direct responsibility for the programs of the Section meetings, as during the life of the Board there were two Committees on Papers, one appointed in November, 1906, composed of Messrs. G. R. Green and C. O. Bond, whose term of office extended to the close of the May, 1907, meeting, and the other appointed in September, 1907, composed of Messrs. C. J. Russell and F. N. Morton, whose term of office will extend to the close of the June, 1908, meeting. The papers read during the year 1907 have been as follows:

"Earlier Illumination and Photometry," by C. O. Bond.

"Incandescent Gas Lamps," by T. J. Litle, Jr.

Informal Lecture on "Electric Lamps," by A. J. Spillman.

"Interior Illumination with Special Reference to this Meeting Room," by T. J. Litle, Jr.

"Engineering Methods Employed in Planning Various Systems of Electric Interior Illumination," by W. A. Kohn.

"Definitions of Some Units Used in Electrical Illumination Engineering," by W. A. Evans.

"Fixture Design From the Standpoint of the Illuminating Engineer," by V. R. Lansingh.

"Inverted Gas Lighting," by M. C. Whitaker.

"The Spectrum," by H. C. Snook.

In addition to the presentation of these papers, a visit was made to the factory of the Welsbach Lamp Company at Gloucester, N. J., in May, a shad dinner being served, and the general impression was that such an outing tended to bind the membership of the Section closer together. The average attendance at the 1907 meetings has been 47 members and 34 visitors. The membership at the beginning of the year was 171, and at the end of the year 181. The Section at present uses as its meeting room the Assembly Room of the Philadelphia Electric Company at no expense. This has kept the Section expenses down to an unusually low figure, the amount of bills transmitted to New York for the year 1907 being $85.69.

In the spring, the Section voted to assess Section dues of 25 cents. These dues are not necessarily annual, but a new assessment will be made when money is needed. Out of these dues have been paid certain expenses in regard to lantern slides for papers.

NEW ENGLAND SECTION.

In conducting the meetings, it has been the aim of the Board of Managers to have each paper presented by the author himself, and to avoid, as far as possible, the reading of papers by deputy. To a great extent this has been accomplished, as with the exception of papers by Messrs. Norman and Keech, all papers were ready by their authors, and at no meeting did there fail to be at least one paper so presented.

At the monthly meetings the following papers have been presented and discussed:

"Photometry of Incandescent Gas Lamps," by T. J. Litle, Jr.

"The Moore Tube," by H. E. Clifford.

"Comparison of Methods of Office Lighting," by E. A. Norman.

"Effect of Frosting on Life of Incandescent Lamps," by A. E. Kennelly.

"Topical Discussion on Photometric Instruments," opened by Geo. C. Shaad.

"Schoolhouse Illumination," by B. B. Hatch.

"Railway Car Lighting," by Geo. C. Keech.

"Report of Committee to Investigate the Question of Standard Type for Photometric Reading," Dr. Bell, Chairman.

"Light and Architecture and Their Relations," by C. Howard Walker.

"Fixture Design from the Standpoint of the Illuminating Engineer," by V. R. Lansingh and C. W. Heck.

"The Variables of Illuminating Engineering," by W. L. Puffer.

"The Effects of Light upon the Eye," by Dr. H. H. Seabrook.

In January, 1907, the membership of the New England Section numbered 83. During the year 33 applications have been passed upon by the Local Board of Examiners and acted upon favorably by the Council of the Society. There have been 5 resignations, one death, and 9 members have been dropped for non-payment of dues. This makes the total membership at writing 101, an increase of 18 over the membership in January, 1907.

NEW YORK SECTION.

At the technical meetings for which the Board of Managers made arrangements, the following papers were presented and discussed:

"Photometry of Incandescent Gas Lamps," by Thos. J. Litle, Jr.

"The Lighting of the Offices of the Consolidated Gas Co.," by Wm. J. Clark.

"Comparison of Methods of Office Illumination," by E. A. Norman.

"The Lighting of Office Spaces," by S. B. Burroughs.

"The Lighting of an Office Building," by Chas. N. Cohn.

Discussions of

(*a*) Modifying effects of reflectors and globes.

(*b*) Comparative rating of inverted and upright gas lamps.

(*c*) Standards of light, primary and secondary.

(*d*) Desirability of combining illuminants of different colors.

"Color Values of Artificial Illuminants," by G. H. Stickney.

"Industrial Plant Illumination," by Geo. C. Keech.

"Fixture Design from the Standpoint of the Illuminating Engineer," by V. R. Lansingh and C. W. Heck.

"Pioneer Electric Lighting," by W. S. Andrews.

"The Relation of Architectural Principles to Illuminating Engineering Practice," by Bassett Jones, Jr.

"The Effects of Light upon the Eye," by Dr. H. H. Seabrook.

In addition, the Board of Managers has appointed a Committee on New Membership, consisting of C. W. Morris (Chairman), W. F. Martin, F. W. Willcox, W. F. Clark, Geo. L. Hunter, W. M. Bauchelle, and L. S. Bigelow.

It is expected that during the next year this committee will be influential in effecting a large increase in the local membership of the Society.

During the year 1907, 89 new names have been added to the membership roll. Seventeen members have resigned, and 30 have been dropped for delinquency in dues. Mr. A. S. Mallory and Mr. J. W. Lewis have died during the year, making a total decrease of 49 members, and an increase in membership of 40, bringing the total to 323 from 283 in January, 1907.

The report of the Finance Committee of the Society rendered in November, 1907, showed that the annual general expenses per member total $4.50, leaving 50 cents per member per year for sectional expense. On the basis of a local membership of 323, there becomes available the sum of $161.50. The Section expenses, roughly, are as follows:

Stenographic reports of local meetings	$210.00
Notices of local meetings	40.00
Postage	10.00
Hall rental in the United Eng. Societies' Bldg.	157.50
Total	$417.50

That the sum available for the discharge of sectional expenses is entirely inadequate is therefore apparent. The situation has occasioned considerable uneasiness in the General Council of the

Society, the Finance Committee and the Board of Managers. The latter body found it unnecessary to incur any expenses for hall rental prior to the autumn of 1907, the Auditorium of the New York Edison Co. being placed at its disposal free of charge. As conditions were such as to prevent the New York Edison Company from extending this courtesy during the past winter season, and as it was not found practicable to secure a suitable meeting room free of charge elsewhere, the hall in the Engineering Societies' Building was rented for the sum of $17.50 per meeting.

It is possible that the revenues of the Society may be so increased during 1908 that no deficiency need be anticipated, but the outlook is serious.

The accessions to the membership during the past year have been much smaller than they should have been. The local membership should be double that at present on the list.

A RECTILINEAR GRAPHICAL CONSTRUCTION OF THE SPHERICAL REDUCTION FACTOR OF A LAMP.[1]

BY DR. A. E. KENNELLY.

The Rousseau diagram for determining the mean spherical intensity of a luminous source is too well known to need detailed description.[2] It consists essentially of a graphical construction based on the mean polar curve of luminous intensity, which yields the mean spherical intensity as the area of a certain figure bounded by straight lines. As soon as this area has been measured, either by the planimeter or equivalent device, the mean spherical intensity of the luminous source is immediately determined.

It is the purpose of this article to describe a construction which has been devised by the writer to expedite such enquiries, and which arrives at the same result in the form of a straight line capable of being immediately scaled, without requiring any planimeter or area measurement. The new diagram is therefore much simpler than the Rousseau diagram of equal number of zones, easier to remember and to apply, is swifter, more nearly accurate under practical conditions of planimetry, and requires only a pair of compasses and an angle protractor for application to the polar curve.

The new diagram can, perhaps, best be explained by referring to an actual example, Fig. 1. The curve O E F G K L represents the polar distribution curve of a particular luminous source occupying the virtual point O. This curve has been taken as a segment of a circle, with diameter O G taken as unity, and depressed 45° below the horizontal plane O H. The reason for selecting such a circular polar curve is that its mean spherical intensity is easily computed, in the manner set forth in the Appendix. It follows from the computation that the mean spherical intensity of this polar curve, assumed as uniform in

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[1] A paper read before the New England Section of the Illuminating Engineering Society, February 18, 1908.

[2] "A Treatise on Industrial Photometry," by A. Palaz. 1894, page 20. Transactions of the Illuminating Engineering Society, Vol. II, April 1907, No. 4, page 217, Fig. 8.

azimuth about the vertical VV′, is 0.593 in terms of the intensity O G as unity. The new construction is as follows:

First select the number of zones to be employed in altitude. In Fig. 1 there are three such zones, of 45° each. The upper hemisphere has one 45° zone, H O B. The lower hemisphere has two 45° zones, i. e., H O G and G O V′. Mark off the middle angular points of the zones, viz., O E, O F, and O K, which will be at elevations of $+22\frac{1}{2}°$, $-22\frac{1}{2}°$ and $-67\frac{1}{2}°$ respectively.

Commence, say, in the upper hemisphere. With center O and the radius O E of the midzone, draw the arc A E B through an angle of 45°. Draw the line O B to the end of this arc.

Turning next to the lower hemisphere, describe an arc with center O and the radius O F of the first midzone, to M, through 45°. Connect O and M by the line O M. Measure back along M O a distance equal to the radius O K of the second midzone, and mark off this distance at a point which shall serve as the center of the next arc. It happens in this particular case that the new point coincides with the point O. With that point as center, and with radius O M, draw another 45° arc from M to V′; so that O V′ makes an angle of 45° with O G, and also 90° with O H. Draw the line O V′.

Take any convenient point, such as H, on the horizontal line, and draw a perpendicular QQ′ through the same, parallel to VV′. In some cases it may be convenient to employ VV′ itself, without erecting the new vertical Q Q′. Project the terminal points B and V′ horizontally upon Q Q′. Bisect the intercept QQ′ in R. Then either the distance Q R or Q′ R will be the mean spherical intensity of the luminous source, to a degree of approximation depending upon the accuracy of the graphical construction and upon the number of zones selected. In Fig 1 the distance Q′ R is 0.598 if O G is unity. It is easy to show that if the geometrical construction were made without error, and Q′ R were scaled correctly, the length would be 0.5973 as far as four significant figures. Comparing the actually measured length 0.598 with the theoretically deduced value of 0.5933, given in the Appendix, it will be seen that in this instance, with only three zones, the result of the graphic construction is correct within 1%. As a general rule, however, 45° zones may introduce an error of two or three per cent. The apparent spherical reduction factor = Q′ R/O h.

Moreover, since the total flux of light emitted by a virtual

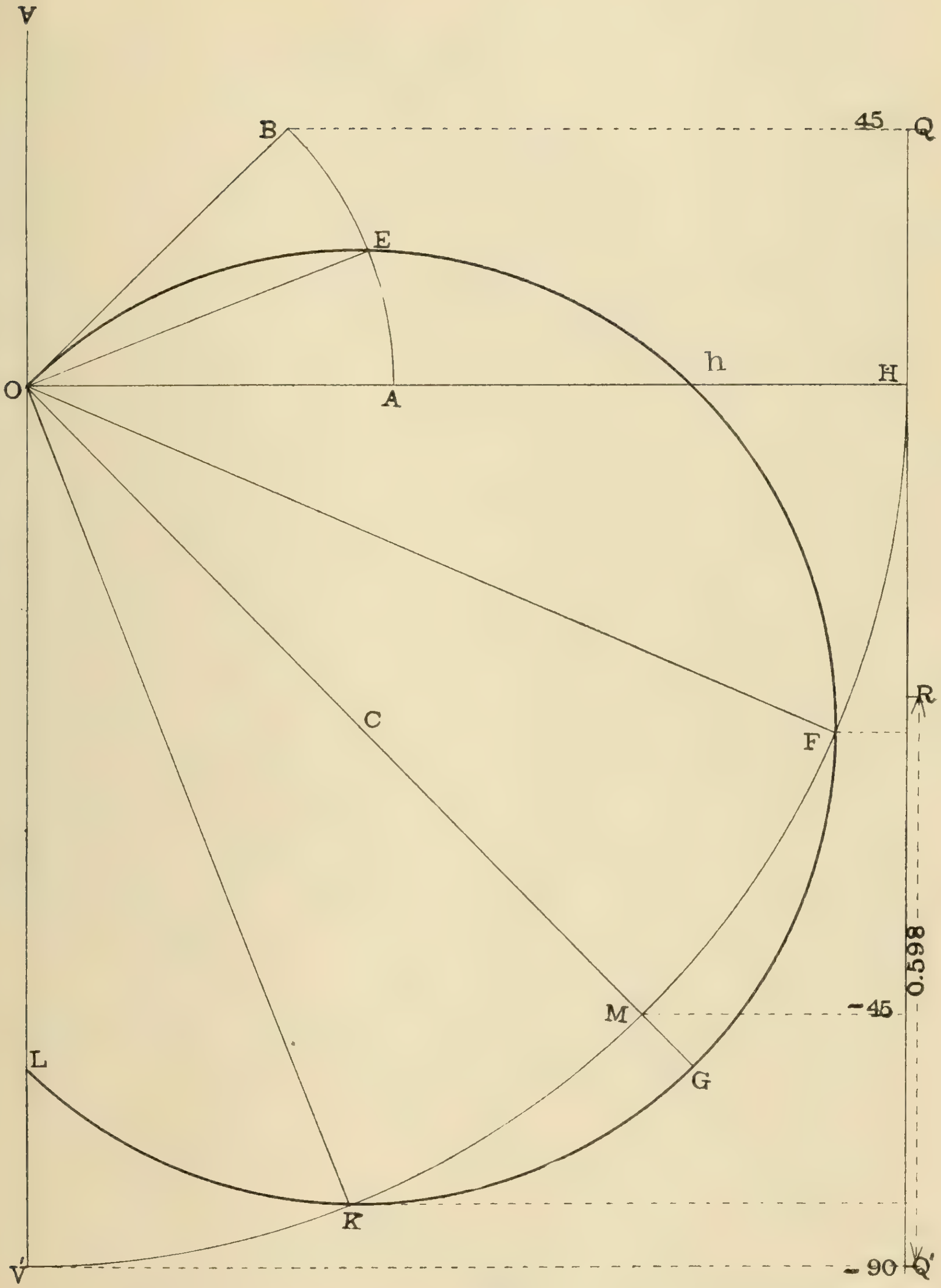


FIG. 1.—NEW DIAGRAM OF SIMPLE CIRCULAR POLAR CURVE DEPRESSED DIAMETRICALLY 45°. RECTIFIED BY 45-DEGREE ZONES.

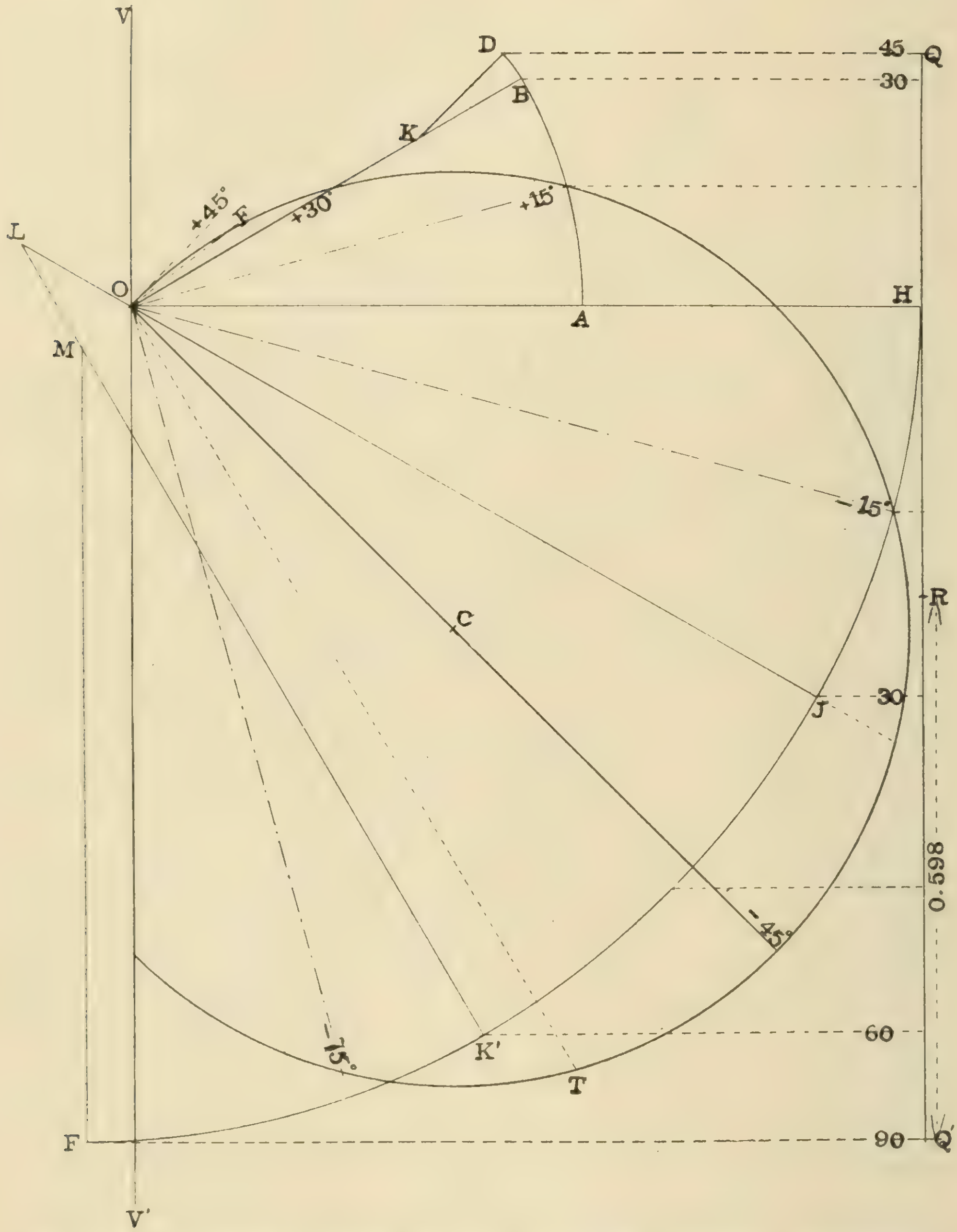


FIG. 2.—NEW DIAGRAM OF SIMPLE CIRCULAR POLAR CURVE DEPRESSED DIAMETRICALLY 45°, RECTIFIED BY 30-DEGREE ZONES.

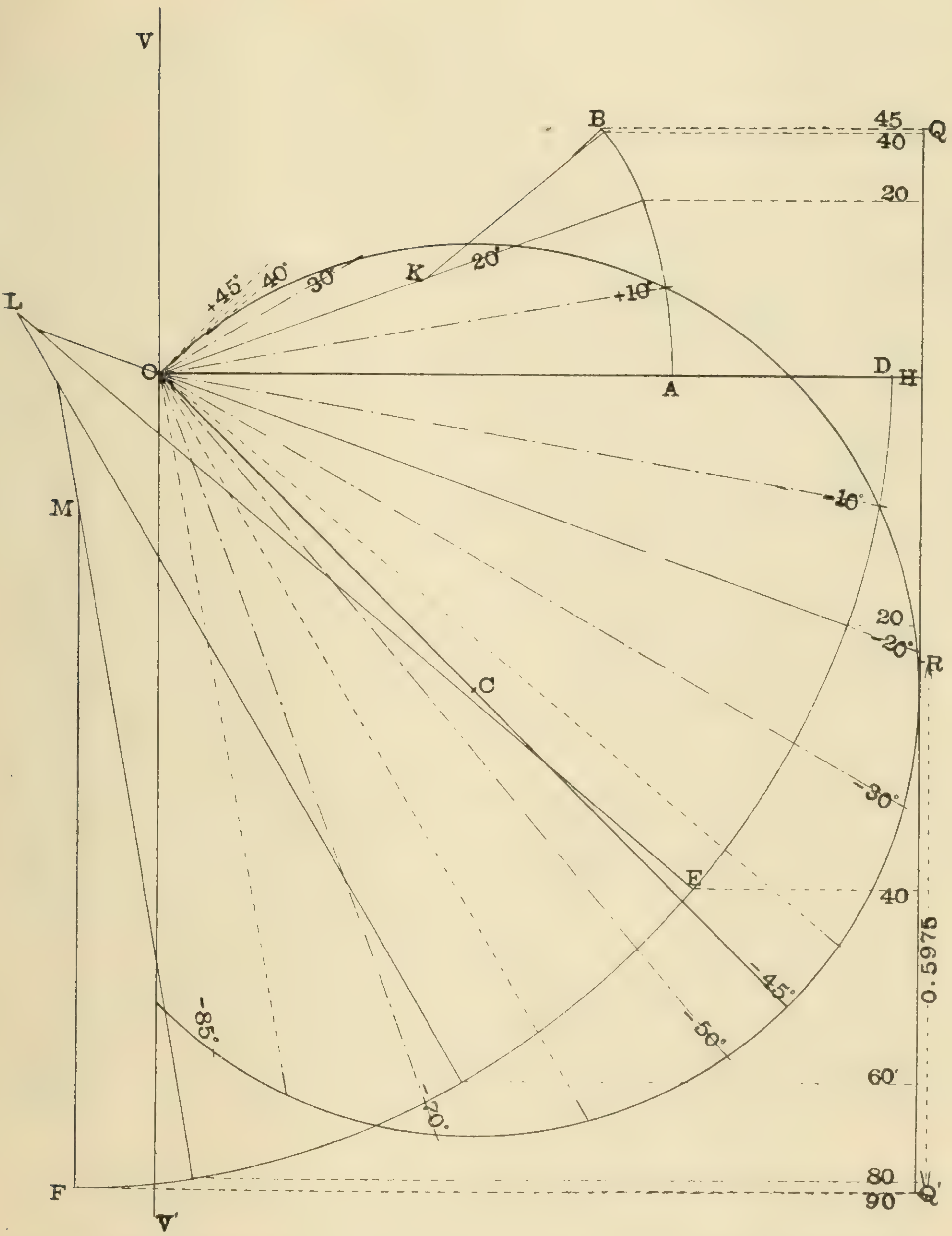


FIG. 3.—NEW DIAGRAM OF SIMPLE CIRCULAR POLAR CURVE DEPRESSED DIAMETRICALLY 45°, RECTIFIED BY 20-DEGREE ZONES.

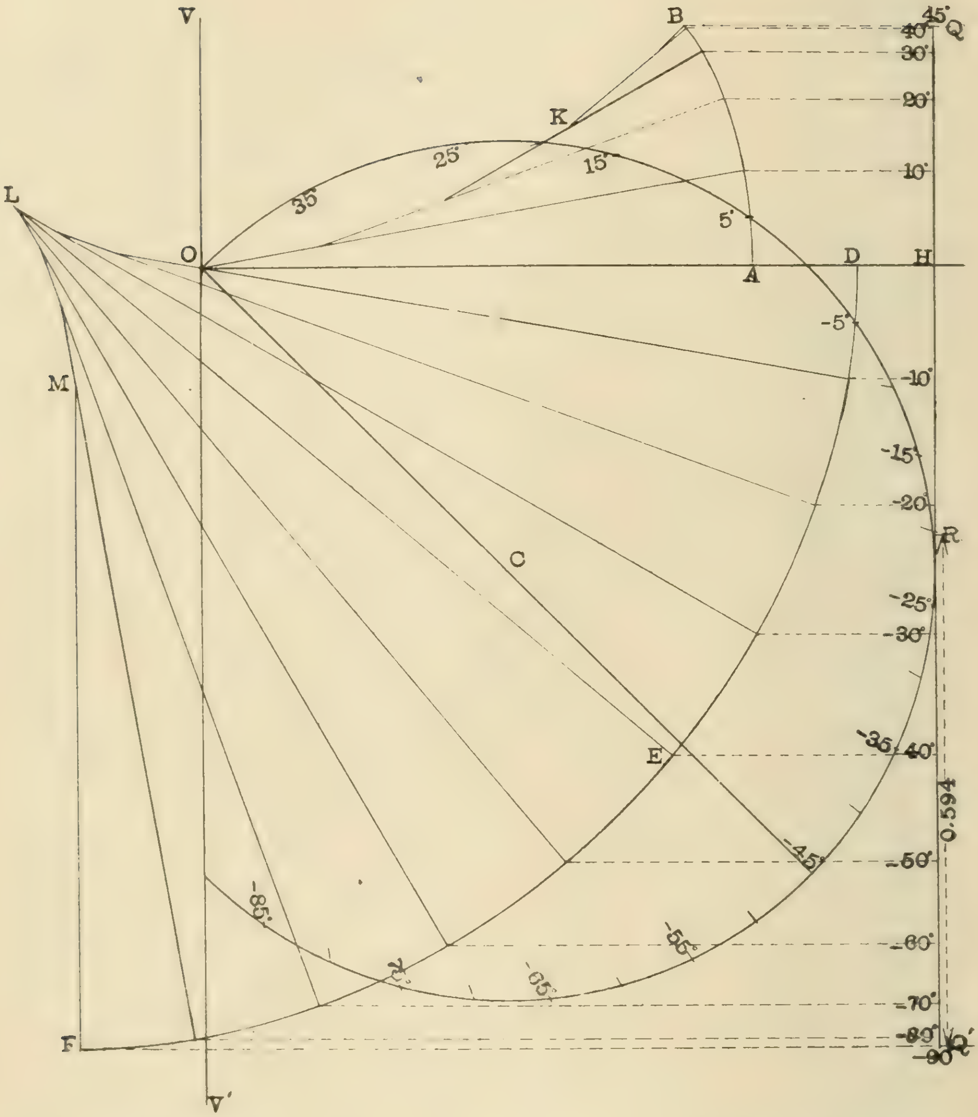


Fig. 4.—New Diagram of Simple Circular Polar Curve Depressed Diametrically 45°, Rectified by 10-Degree Zones.

point source is 4π times its mean spherical intensity, it follows that if a circle were drawn with radius $Q\,Q'$, the length of the circumference would be equal to the total luminous flux emitted by the source O. Further, if the polar intensities are scaled in candle-power, then $2\pi\,Q\,Q'$, or $7.52 \times OG$ will be the total luminous flux in candle-lumens. If the polar intensities are scaled in hefners, then $2\pi\,QQ'$ will be the total luminous flux in hefner-lumens. Further, the total flux in the upper hemisphere will be $2\pi\,Q\,H$ lumens, and the total flux in the lower hemisphere will be $2\pi HQ'$ lumens. If we should desire to know how much flux is emitted between the horizontal plane and the depression-angle $45°$, we should measure $H-45$, and multiply by 2π. Similarly 2π times the distance along $Q\,Q'$ between any two projected points is equal to the total flux emitted in the angular zone between the corresponding points in the polar curve. Or, expressing the same condition in another way, the distance along QQ' between any two projected points is numerically equal to the flux in lumens per radian of azimuth, emitted in the corresponding zone on the polar diagram.

Again, $H\,Q$ is the mean upper hemispherical intensity, $H\,Q'$ is the mean lower hemispherical intensity, and the mean spherical intensity is seen to be the arithmetical mean of these two hemispherical intensities.

In Fig. 2 the same construction is repeated, using zones of $30°$, instead of zones of $45°$. We thus introduce more steps into the geometrical work; but we tend to attain a higher degree of precision in the final result.

As before, mark off the zones of $30°$, viz., A O B in the upper hemisphere, and H O J, J O T and T O V′ in the lower hemisphere. Then mark off the middle angular points in these zones at $+15°$, $-15°$, $-45°$ and $-75°$ respectively. These points on the polar curve will form the successive radii of the arcs to be drawn.

Commencing, say, with the lower hemisphere, with center O and radius O $-15°$, draw the $30°$ arc H, $-15°$, J. Join O J. With distance O $-45°$, the second midzone radius, measure back, along J O produced, a distance J L. With center L and radius O $-45°$, continue the arc downwards from J through $30°$ to K′; so that J L K′ $= 30°$, and L K′ makes an angle of $60°$ with a horizontal through L. Join L K′. With distance O $-75°$, the third midzone radius, measure back along K′ L a distance K′ M.

With center M and radius O $-75°$ continue the arc downwards from K′ through $30°$ to F. Join M F which will be parallel to V V′.

Turning to the upper hemisphere, with center O and radius $o+15°$ of the first midzone, describe the arc A, $+15°$, B. Join O B, which will make an angle of $30°$ with O A H. There now remains only part of a zone to be covered in the polar curve; namely the zone $+30°$, O, $+45°$. Take the middle angular point O F, at the elevation $+37\frac{1}{2}°$. With distance O F, measure back along B O the point K. With center K and radius O F, continue the arc from B upwards for $15°$ to D. Join K D, which will be inclined at an angle of $45°$ with O H.

Project horizontally the terminal points D and F upon any convenient vertical line Q Q′. Bisect Q Q′ in R. Then Q′R will be the mean spherical intensity. In Fig. 2 this distance measures 0.598, if O G is unity, or the same as in Fig. 1. Since the horizontal intensity O H is 0.7071, the apparent spherical reduction factor by either of the constructions in Figs. 1 and 2 is $\frac{0.598}{0.7071}$ $= 0.846$, or 84.6%.

The same process of construction is followed in Fig. 3, on the same polar curve; except that the zones are of $20°$ instead of $45°$, or of $30°$. Unless the more numerous steps in the geometrical work offset the greater degree of precision in selecting the midzone radii, we should expect a greater degree of accuracy in the result. The curve of arcs in the upper hemisphere consists of two $20°$ arcs with radii of O and K respectively, followed by a little $5°$ arc at B, with the radius at $o + 42\frac{1}{2}°$ the middle of the zone left over. In the lower hemisphere the curve of arcs proceeds by $20°$ shifts along D E F until the last one which is the $-80°$, $-90°$ arc and which is drawn for $10°$ only, with the radius O $-85°$ on the polar curve. Finally half the distance Q Q′ measures 0.5975 on the diagram, which is within 0.76% of 0.5933, the theoretically correct value.

Finally, the same process of construction is presented in Fig. 4, applied to the same polar curve, but working with $10°$ zones. The half of the projected distance Q′R measures 0.594, which agrees with the theoretically correct value within 0.17%, or about one part in 600.

In practice, $20°$ zones are recommended for reliable work, and in many cases $30°$ zones are sufficiently small; because the

degree of precision of the polar curve rarely warrants a higher degree of geometrical work than 30° zones will produce. It is unlikely that zones smaller than 10° will be found advantageous.

Referring particularly to Fig. 4, it will be seen that the geometrical process resolves itself into producing from the given polar curve two other curves and a straight line of projection. The first curve of arcs, D E F or A B, may be called the involute curve. The second curve of centers, O L M or O K B, may be called the evolute curve. Successive tangents on the evolute curve form successive normals to the involute curve. Moreover, if a string without slack were fastened at L of length equal to the maximum intensity O—45°, and were furnished with a pencil at the free end; then after sticking pins in the paper at the successive centers, M O, etc., the string, when moved from one side to the other, would describe with the pencil the involute arc D E F. The same condition applies to the upper hemisphere.

Theory of the Method.

The mean spherical intensity of a luminous source having equal intensities in azimuth and occupying a virtual point is

$$I_m = \tfrac{1}{2} \int_{\frac{-\pi}{2}}^{\frac{\pi}{2}} I_\theta \cos\theta \, d\theta \qquad \text{candle-power or hefners} \quad (1)$$

where I_θ is the luminous intensity at the elevation θ. Let there be n equal zones each of $\frac{\pi}{n}$ radians. Then the above equation becomes:

$$2I_m = \int_{\frac{-\pi}{2}}^{\frac{-\pi}{2}+\frac{\pi}{n}} I_\theta \cos\theta \, d\theta + \int_{\frac{-\pi}{2}+\frac{\pi}{n}}^{\frac{-\pi}{2}+\frac{2\pi}{n}} I_\theta \cos\theta \, d\theta + \dots$$

$$+ \int_{\frac{\pi}{2}-\frac{2\pi}{n}}^{\frac{\pi}{2}-\frac{\pi}{n}} I_\theta \cos\theta \, d\theta + \int_{\frac{\pi}{2}-\frac{\pi}{n}}^{\frac{\pi}{2}} I_\theta \cos\theta \, d\theta \qquad \text{hefners} \quad (2).$$

In each of the above n terms, I_θ can differ but little from its value at the midzone. We can therefore write without much error:

$$2I_m \cong I_{-\frac{\pi}{2}+\frac{\pi}{2n}} \int_{\frac{-\pi}{2}}^{\frac{-\pi}{2}+\frac{\pi}{n}} \cos\theta \, d\theta + I_{-\frac{\pi}{2}+\frac{3\pi}{2n}} \int_{-\frac{\pi}{2}+\frac{\pi}{n}}^{\frac{-\pi}{2}+\frac{2\pi}{n}} \cos\theta \, d\theta + \dots$$

$$+ \; I_{\frac{\pi}{2}-\frac{3\pi}{2n}} \int_{\frac{\pi}{2}-\frac{2\pi}{n}}^{\frac{\pi}{2}-\frac{\pi}{n}} \cos\theta \, d\theta + I_{\frac{\pi}{2}-\frac{\pi}{2n}} \int_{\frac{\pi}{2}-\frac{\pi}{n}}^{\frac{\pi}{2}} \cos\theta \, d\theta \qquad \text{hefners} \quad (3).$$

It will be seen by inspection that the construction in Figs. 1–4 makes $QQ' = 2I_m$ and that the projection of each arc in the involute curve on the line QQ' corresponds to one term on the right hand side of (3)

The construction of the involute curve may be seen to express the relation

$$s \cong \int_0^{\frac{\pi}{2}} I_\Theta \, d\theta \qquad \text{units of length}$$

and

$$\int_{-\frac{\pi}{2}}^{0} I_\Theta \, d\theta \qquad \text{units of length}$$

in the upper and lower hemispheres respectively.

When the zones are taken of 20°, it is advantageous to select as their midangular elevations +80°, +60°, +40°, +20°, +0°, −20°, −40°, −60°, −80°. This leaves no uncompleted arc at either terminus, and it avoids any discontinuity in the involute curve at the horizontal line. The first arc is drawn from +10° to −10° with the radius equal to the mean horizontal intensity.

APPENDIX.

Since it is sometimes useful to draw a circular polar curve of readily calculable mean spherical intensity, we may consider the general case presented in Fig. 5 of a circular curve of maximum

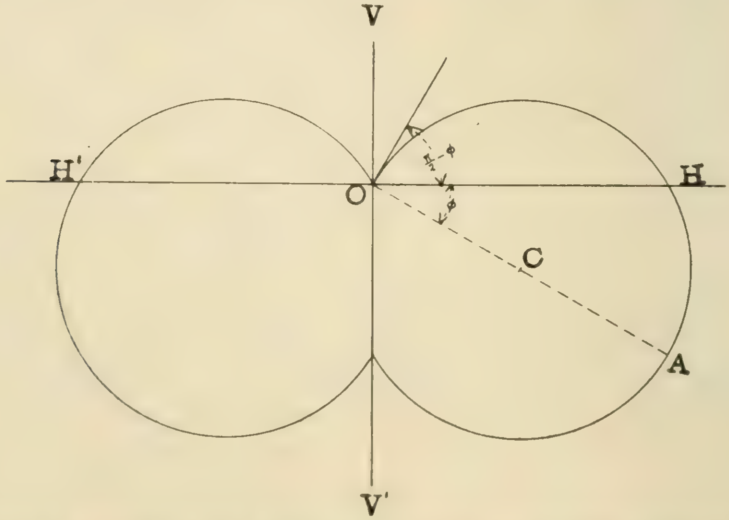


FIG. 5.—SIMPLE CIRCULAR POLAR CURVE DIAMETRICALLY DEPRESSED THROUGH ANGLE Φ.

intensity I at the diameter O A, which is depressed through an angle $\Phi°$ below the horizontal O H. Then the intensity at any angle of elevation $\theta°$ is $I_\Theta = I \cos(\theta + \Phi)$ candle-power or hefners. The mean spherical intensity of the source will then be :

$$I_m = \tfrac{1}{2} \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}-\Phi} I \cos(\theta + \Phi) \cos\theta \, d\theta \qquad \text{candle-power or hefners.}$$

$$\text{or} \quad 2\, I_m = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}-\Phi} I \left\{ \cos^2\theta \cos\Phi - \sin\theta \cos\theta \sin\Phi \right\} d\theta$$

$$= I\cos\Phi \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}-\Phi} \cos^2\theta \, d\theta - I\sin\Phi \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}-\Phi} \sin\theta \cos\theta \, d\theta$$

$$= I\cos\Phi \left[\frac{\theta}{2} + \frac{\sin 2\theta}{4} \right]_{\frac{\pi}{2}}^{\frac{\pi}{2}-\Phi} - \frac{I\sin\Phi}{2} \left[\sin^2\theta \right]_{-\frac{\pi}{2}}^{\frac{\pi}{2}-\Phi}$$

$$= I\cos\Phi \left\{ \frac{\pi}{4} - \frac{\Phi}{2} + \frac{\sin(\pi - 2\Phi)}{4} + \frac{\pi}{4} + \frac{\sin \pi}{4} \right\}$$

$$- \frac{I\sin\Phi}{2} \left\{ \sin^2\left(\frac{\pi}{2} - \Phi\right) - \sin^2\left(\frac{-\pi}{2}\right) \right\}$$

$$= I\cos\Phi \left\{ \frac{\pi}{2} - \frac{\Phi}{2} + \frac{\sin 2\Phi}{4} \right\} + \frac{I\sin\Phi}{2} (\sin^2\Phi)$$

$$= \frac{I}{2} \left\{ \cos\Phi\, (\pi - \Phi) + \sin\Phi \right\}$$

$$I_m = \frac{I}{4} \left\{ \cos\Phi\, (\pi - \Phi) + \sin\Phi \right\} \qquad \text{candle-power or hefners.}$$

$$\text{When } \Phi = 45° = \frac{\pi}{4},\ I_m = \frac{I}{4} \left\{ 0.7071 \left(\frac{3\pi}{4} + 1 \right) \right\}$$

$$= 0.5933 I$$

Since the spherical reduction factor is $f = \dfrac{I_m}{I_o}$ where I_o is the mean horizontal intensity, and $I_o = I \cos\Phi$, we have

$$f = \frac{\frac{I}{4} \left\{ \cos\Phi\, (\pi - \Phi) + \sin\Phi \right\}}{I \cos\Phi} = \frac{(\pi - \Phi) + \tan\Phi}{4}$$

$$\text{When } \Phi = \frac{\pi}{4},\ f = \frac{\frac{3\pi}{4} + 1}{4} = 0.8391$$

ARTIFICIAL ILLUMINATION FROM A PHYSIOLOGICAL POINT OF VIEW.*

By Dr. Myles Standish.

The old proverb, "seeing is believing," is not true at all. Seeing is not believing. Feeling is believing. We see very little; that is, our eyes see very little. They see nothing but light as expressed in ordinary illumination, in shadow and in color. Everything else that we "see,' we perceive as the result of experience. We say we see that this surface is polished. We do not see that it is polished. We see that it reflects light in a certain manner and we have at some time investigated that surface with our fingers, and have come to find that a certain reflection of light means a polished surface. So also with rough surfaces, with solidity, with projection, with perspective, with distance, with everything. We get a certain amount of light and then by actual experience we find out how to interpret that light. Therefore in considering illumination we must take a few of these things into account.

That interpretation is the greater part of seeing is very picturesquely shown by patients who have been born with, and have grown up with cataracts and have then been operated upon and been able to see. A gentleman in Philadelphia operated upon a negro woman who had been a slave before the War and had always lived in the same house and done domestic work, such as washing dishes, etc. After the War closed, the family was broken up and the woman thrown on her own resources, it became necessary that she should earn her own living, and therefore that she should be able to see. After an operation for cataracts she could see with the aid of the proper lenses. At first she did not know the difference in appearance between a teacup which she had been washing and a cat in the corner. She had no reason to be able to tell which was the cat and which the teacup. It was simply a lack of knowledge with her, although her eyes were performing their proper functions. A number of years ago, one of my eminent German colleagues operated on a girl of 14, and with true

* A paper read before the New England Section of the Illuminating Engineering Society, March 17, 1908.

German thoroughness kept bandages over the girl's eyes for weeks after the operation, so that she should not be able to acquire any ability to interpret her visual images. He tried several experiments upon her with glasses. He records that it was seven days after the child could see very well before she recognized a fork when she saw it, although she had been using a fork for many years. It was seven days further before she recognized the picture of a fork as representing a fork. There was no relationship between the two to her mind.

The above facts are related to show that almost all of that vision which we call sight is experience. Art itself is a pure convention. Some years ago I gave a lecture on art from an oculist's point of view, in which I said that art was a convention—something we acquired, and not a thing that we recognized because we saw it in the first place, and that it was possible that a civilization should come up which would have an entirely different expression of art from that which we have. Dr. Sturgis Bigelow, in the discussion which followed, said that it was a curious commentary on my remarks that Chinese artists, whose pictures we consider to have no perspective, criticise Western art and say that it is all very good, but has no perspective, showing that they have an entirely different view of perspective from ours. Now we work out perspective mathematically and assume that our expression of perspective must be correct, but we get our ideas of solidity and distance through our eyes largely by experience. Of course we have two eyes, and these two eyes give a slightly different view of each object, and in that way are helped to judge of solidity, distance and shape of a body, as far as the dimensions go. The shadow tells us that it is solid, that it has a certain length, and from the way in which the shadow falls, we estimate the solidity, etc., of the object.

You are all entirely familiar with that trick diagram which contains a square, and inside it another square, with a line drawn from the corners of the interior square to the corners of the exterior square. You look at it and it seems to be a truncated pyramid coming toward you. After a moment or so, the thing seems to be reversed, and the truncation seems to be in the other direction. It changes before our eyes from one condition to the other. I presume the explanation of it is that it is entirely our mental conception as to which of those lines are nearer to us, and there

being no shadows from it we have no means of judging which is actually nearer.

Shadows are an important factor in our judgment of what we see. The light which enters the eye, coming through the diaphragm of the pupil and focused by the lens, falls upon the retina. The retina is a differentiated lengthening of the optic nerve so constructed so as to receive the pictures presented by the rays of light and forward them to the brain. This retina is largely composed of rods and cones. They are a sort of Telford pavement stood up on end. The exact use of rods and cones is not entirely determined. We do, however, know several things about them. We know, for instance, that in the macula is the most distinctive vision and a few degrees away from that small central area the objects become more or less blurred and out on the periphery one can barely see color, whether it is light or dark. The central area of acute vision is composed exclusively of cones, and from that area to the periphery there is a mingling of rods and cones, and nearer the periphery the rods predominate or become very greatly increased. The exact function of the rods as differentiated from the cones is not known. We do know that the rods contain a chemical agent which is exhausted or used up by light and replaced with great rapidity when the eyes are used in the dark, or with almost instantaneous rapidity when the eyes are used under ordinary circumstances.

The fanciful tale of photographing the retina of murdered persons and getting pictures of the murderer, is, of course, a myth founded upon some such experiment as the above. If a brilliant white illuminated paling against a dark background is placed before the eye of an animal so that the image must fall in one place, practically all of the light falls in the shape of that image, and the visual purple is exhausted; if the animal is killed and chemical reactions are made, there may be obtained a sort of rough diagram.

In the eyes of people who have been out on the snow for a long time, or people who have had very large pupils from some cause and are out on the snow so they get a large amount of light in their eyes, the purple becomes wholly exhausted if they enter a place that is not so brightly lighted, all objects appear red. The exhaustion of the visual purple even when to a less extent may still be undesirable. The eye, of course, adjusts itself to light.

It does that perhaps largely by the pupil which contracts in bright light and expands in darkness or in shadow. It is not necessary for light to come through the pupil in order to make the pupil react. If the eye is so placed that the entire cornea; that is, the transparent portion which covers the iris, and the pupil is shaded from the light and only the white portion of the eye exposed, the turning on or off of the light which falls upon the white portion will be registered with absolute accuracy by the contraction and dilation of the pupil, showing that the amount of light which comes through the white sclera is sufficient to produce prompt reaction of the pupil. Therefore the effect on the eye cannot be estimated entirely by the pupil, as many people attempt to do.

Bright light is tiresome from whichever direction it comes to the eye, but it is much more tiresome and much more exhausting if it comes from unusual directions. Under nearly all normal conditions the light comes from above. The eye is protected from light from above by the bony shelf which projects forward over it so that the light does not fall upon the white portion of the eye very strongly. The reason for snow blindness is probably not only the great intensity but largely the fact that the light comes from the wrong direction. It is the light which comes directly from below and falls largely on the white portion of the eye or going through the pupil falls on that portion of the retina which is not accustomed to receiving bright light, which is so harmful.

Incandescent lamps should never be placed in such position that they will be continuously in the visual field. Indeed, when the lamp is so placed it produces disastrous results. The difference in the illumination between the object looked at and the surrounding objects is one of vital importance. An opaque shade, throwing the room into absolute darkness, especially if the room is darkly decorated, and throwing the light down upon the book one looks at, is a very undesirable device. When the rest of a room is dark, the greater the illumination in one spot, the more undesirable it is.

Many people having trouble with their eyes under the above conditions, substitute 16-cp. lamps for 8-cp. units, keeping the surrounding conditions the same, and subsequently they ask, with great seriousness and considerable asperity of tone, if electric lamps are bad for the eyes. Of course, they are injurious for the eyes, if improperly used. Bookkeepers are often subject to

annoyance from poor lighting. They open out their book on their desk, hang a lamp from above about on a level with their eyes, to throw light down on the book and then put an absolutely opaque shade around it to protect their eyes. They are probably in the back of the office, while the gentleman who runs the business and does not have to use his eyes so much, sits up in the window. The walls of the room and everything else except the book that the bookkeeper is working on are probably dark. When a man under these conditions is persuaded to turn the lamp and throw the light away from himself and toward his book so that he will not get all the intensity of the light reflected from the paper directly into his eyes, and at the same time light up the walls of the room in front of him so that the periphery of the field is illuminated as well as the centre, then he has no further need of an oculist's services.

The science of artificial illumination from the oculist's point of view, consists in only a few things. First, the bare filament, or bare incandescent gas mantle or anything of that sort, should never stand in constant relationship to a man's eyes when he is working in a given place. Better yet, they never should be exposed to his eyes. They should be high enough so that the general illumination should come from filaments which are not seen. It is also desirable that the illumination on the page should be only slightly greater than the general illumination. When a pencil is put down on the paper the shadow which comes from the special illumination should be only slightly dominant. It should be simply darker.

Constant irritation of the retina from alternating light and shadow wearies the eye, and that is the source of annoyance when one has a lamp to the right when writing with a pen. When the shadow of the pen is constantly moving up and down across that which one has just written so that at one moment it is in the bright illumination and the next in shadow, ocular fatigue is produced.

The room itself must be fairly illuminated and the light must not fall into the eye. The light must come from above, the direction to which we are accustomed. The lamp should be so placed that the light will not be reflected brilliantly from below into the eyes. Practically normal lamps produce shadows and any form of illumination which is so brilliantly achieved that shadows are eliminated is always annoying, probably because the eye recog-

nizes a condition in which it cannot judge, if seeing is judging, with the accuracy with which it should, and it is constantly adjusted and readjusted in an effort to make known objects appear more natural.

The proper amount of light seems to be a little more difficult to determine. It is true, of course, that the amount required varies with different individuals. Some people are more sensitive to light than others, and in olden times it may have been a general fault that there was not light enough. In general illumination it is true at the present time that we have too much light as a rule. Everybody seems to desire as much light as possible. More light than is necessary is harmful.

I do not pretend to say at the present moment how much light is necessary for any given purpose, but as to how it should be directed, I have very positive opinions, as stated above.

DISCUSSION OF DR. STANDISH'S PAPER BY THE NEW ENGLAND SECTION.

Mr. J. S. Codman.—A considerable amount of work must be conducted to educate the people to appreciate the harmful effects from bare lamps. The general public oppose the use of frosted bulbs and shades, and demand bare filament lamps, even when they are of the high efficiency tungsten type.

Dr. Williams.—A very desirable paper for the use of bookkeepers is one without gloss, but having a decidedly yellow tint. The basis of all comparative vision is the difference in the illumination of the different objects. It depends somewhat on the difference in color, but mostly on the difference in luminosity, which depends on the co-efficiency of reflection of these surfaces. The greater the reflection the greater will be the illumination and the better will be the light in the room. With ordinary white paper and with light colors the co-efficiency of reflection will probably not be over .6. The co-efficient falls rapidly when any colors are mixed with the white. The best colors are the whites and yellows; then there is a rapid falling off through the greens, reds, browns, etc., and there are colors which reflect only about .2 or less of the incident light.

When the light comes from a mercury-vapor lamp a sharper focus is obtained, because the red rays are eliminated. It is to be remembered that there is a difference of nearly 1-2 m. m. in the focal point of the red and the blue rays in the human eye. With ordinary lamps the light intensity is so much greater in the yellow and the yellow green that we practically focus our eyes for that part of the spectrum and get a very satisfactory definition. With the mercury-vapor lamp there is sometimes a sense of fatigue after continued use brought on by the fact that the eye is being supplied with only a part of the light to which it has become adapted, and when the red components is omitted the loss is noticed.

The light from the mercury vapor lamp is poor in red rays, but rich in actinic rays. The short wave length, which are irritating to the eyes, can be eliminated by the use of amber glasses. Such glasses decrease the luminosity somewhat, but even a mercury-vapor lamp depends very little upon the blue-violet rays for its luminosity, the best light coming from the yellow and green.

Mr. Grifford.—A convenient method of determining whether a lamp filament is too brilliant consists in noting the duration of the image remaining when one closes his eyes after viewing the filament. If no image remains, it is probable that the brightness is not great enough to cause eye trouble.

Dr. Standish.—The test suggested by Mr. Grifford is a good one. The value of the intrinsic brilliancy which will produce an after-image, and also which will cause eye trouble, depends upon the background. Modern incandescent lamps are too brilliant for use with black background. One finds it disagreeable to use red paper, a better color being yellow, which, in fact, is less fatiguing than pure white. It is probable that part of the disagreeable results with red is attributable to the absence of actinic rays. Gloss is not an objectionable feature of a paper, provided the light is obtained from such a direction that none is reflected into the eyes.

DISCUSSION BY THE CHICAGO SECTION OF DR. H. H. SEABROOK'S PAPER "THE EFFECTS OF LIGHT UPON THE EYE."*

Dr. Edward T. Gardner.—Daylight, not sunlight, is the natural light. The light given by Nature is rich in all that we need. Daylight is a tonic for the eye. However, since our natural luminary is doing business elsewhere a part of the time, we must find a substitute, and there is no doubt that a good kerosene lamp is the best substitute known.

The effect of light upon the normal eye, when the illumination is moderate, is perfectly physiological and has no ill results. The kerosene lamp is a standard substitute for daylight; it gives sufficient light and a good quality of light. Now, if the kerosene lamp be compared with the electric lamp it will be found that so far as the quality is concerned they are very similar.

The electric lamp has caused more trouble in recent years than has the kerosene lamp, more on account of quantity than of quality. In light, as in some other things, we Americans are rather vulgarly inclined. When it comes to quantity our prodigality is vulgar. Illuminating engineers demand an excess of light. Brilliant illumination suggests opulence, therefore, it must be had. In many instances the expense is the only thing that prevents the brilliancy becoming so great as to effect eyesight.

In the incandescent electric lamp the small area of the filament is the source of enormous illuminating power. Its intensity is so great that the eyes are injured when directly exposed to it. Every effort should be made to abolish the clear glass bulb when it is so located that the light rays inpinge directly upon the eye.

The normal eye does not need protection in ordinary light. However, a diseased or weak eye is unable to withstand high luminous density. It is generally conceded that the light produced by a good kerosene lamp is the best artificial illumination for close work. The light of the incandescent electric lamp is acceptable so far as its color is concerned, but the brilliancy of the filament is too great, and an exposed filament is harmful to the eye. A ground-glass globe is effective in decreasing the

* See page 156 of the February issue of the *Transactions*.

brilliancy, but it absorbs about 25 per cent. of the light. Illuminating engineers should educate the people to appreciate the fact that 75 per cent. light, well softened, is better, in every respect, than 100 per cent. light from an exposed filament.

Dr. George F. Suker.—In thanking the Illuminating Engineering Society for its invitation to the Chicago Ophthalmological Society to attend its meeting, I wish to express the willingness of the members of the latter society to hold a joint session with the former in the near future in order to discuss fully the subject treated at the present meeting. The incandescent electric lamp, as now constructed and generally used, is a source of great evil. The brilliant filament is very exhausting to the retina of the eye, causing after images which of themselves are sufficient to become irritating. It is not so much the quality of the light as the construction of the lamp that is at fault. Good results can be obtained by covering the lamp, so as to hide the filament under an amber or green tint. A diffused light emanating from a distant source is much better than a direct light from a lamp near at hand. The ordinary clear glass that is used for incandescent lamps is not as good as a tinted one, irrespective of the color, so long as the proper quality of light is obtained for the illumination of a given space. Excessive light is always accompanied by a certain amount of heat, and the heat rays are just as injurious to the eye as any other ray.

The light that is ordinarily furnished for large rooms is usually ample for general purposes, but for close work the results are not satisfactory. I believe it is better for home purposes to have one large central lamp, giving well diffused light, and not a near-at-hand, intense and insufficiently protected lamp, for example, the usual electric study or chandelier lamp. It is best to have a large area well illuminated, so that one particular person cannot assume the greater share of the light. Just as good results can be obtained with a moderate amount of illumination well diffused, as with an intense lamp and poor reflection. A good arrangement is obtained by placing the lamp well away from the eye and using some translucent, not transparent, form of glass.

Dr. Henry Gradle.—An ideal illuminating arrangement would be found in the use of arc-lamps equipped with reflectors for throwing the light against the ceiling and walls. A

reproduction of daylight is what is really wanted. A distinction must be made between the general illumination of a room and the lighting required for close study. In the former instance, where it is not the object to read steadily, the more diffused the illumination the better. It is not desirable in that case to have a very brilliant lamp directly exposed to the eye. On the other hand, when the light is to be used for the purpose of reading, the shade over the lamp should be opaque, in order to throw as much light on the paper as possible, and a polished reflector is decidedly better than a ground glass globe for this purpose.

Considerable eye trouble has been experienced by office men when their eyes have been exposed to the heat directly from a lamp or reflected by glazed paper. Such trouble can be avoided by placing the lamp far away from the eye and arranging for the proper amount of diffused illumination. Electric light, for most purposes, is as good as can be produced. The aim of the illuminating engineer should be to produce light of sufficient intensity with as little heat as possible, and having a color as near daylight as possible.

LIGHTING FIXTURES FROM A MANUFACTURER'S POINT OF VIEW.*

By Mr. F. C. Dickey.

Attention having been directed to a recent criticism to the effect that the lighting fixture manufacturers and dealers generally are lacking in progressiveness, and are from ten to fifteen years behind the times, possibly a few words from a manufacturer's standpoint may not be wholly without interest.

It is to be admitted that the primary idea of establishing a manufacturing plant is to obtain a profit on the capital invested. In order to accomplish this result not only must skill, care and economy be exercised in the conduct of the business, but equally important must it be that the manufacturer produce fixtures which will be quickly purchased by the users, so the business will be continued and become permanent.

The manufacture of lighting fixtures is a complicated process, and one not at all as easy as it looks. There are many elements to be considered and employed before a satisfactory article is produced, and the industry is essentially one which combines the artistic and mechanical in a high degree. The designer, who is also an artist, embodies his thoughts and ideas in a sketch which the artisan reproduces in a tangible and practical manner, out of such refractory materials as brass, iron, glass and combinations of them, so that gas or electricity can be conveyed to the several distributing points of the fixture, and thus be made to serve its purpose of being a source of illumination as well as a pleasant object to the eye.

If the lighting fixture manufacturer is successful he must be progressive, for the law of trade knows no favors, and lack of progressiveness and individuality would soon eliminate such a producer from the field. Hence it follows that if the stock of a manufacturer or dealer contains any fixtures which are of a style which was in vogue years ago, the thought naturally suggests itself that he has not fully realized or appreciated his

* Read before the Philadelphia Section March 20, 1908.

position. If he did, it should quickly have become apparent to him that the proper course to adopt would have been for him to lessen the price on the slow moving articles, so that he could readily dispose of them, and thus make room for more modern and quickly moving pieces, and, accordingly, more profitable ones. This, no doubt, is often done, as the veriest tyro in business matters soon recognizes the fact that the slowest moving stock is the most expensive and the least profitable, by reason of its requiring so much dead capital, which becomes more costly and burdensome every year, due to the accumulation of interest necessary to carry it, and from which no return can be expected.

I do not think, however, that there are many such stocks of fixtures at the present time, and am confident that if access could be had to the records of the manufacturer or dealer it would be found that the majority of the so-called "old styles" are goods which have been only lately manufactured or received from the factory, and are of a staple or standard character, and are being constantly reproduced as a result of the demands of his trade and successive re-orders, and which are so complete or general in character and so fully answer the essentials, that from a trade standpoint, he would be committing a blunder in discontinuing their manufacture.

The manufacturer and dealer are entirely dependent upon their trade for their existence, and if either of them fails to appreciate or grasp the requirements of his trade, he will soon be lost sight of, and while they may be regarded to some extent as the teachers of their clients, and do endeavor to instill more aesthetic ideas in their tastes, none is so situated financially as to be able to take a rock-like stand and offer himself as a willing sacrifice for the sake of the ideal, which, in the majority of cases, would be brushed aside for a more tawdry or showy object anyhow. No manufacturer is in a position, at the present time, to confine himself entirely to purely ideal fixtures and produce enough of them to return a satisfactory profit; whether willing or not, he is compelled to turn out the more showy, even if less artistic, pieces, which please the eye of the greater number. Still the present prominence of the fixture industry is undoubtedly due to the foresight and progressiveness of the manufacturers, stimulated by the demands of the trade and by competition.

and is destined to become even more prominent as the value of fixtures in the decorative art becomes more fully recognized.

Criticism of the manufacturer for lacking in originality and failing to produce something entirely new and different from anything extant is a sweeping one, and one not altogether warranted by the facts. It must be borne in mind that he is handicapped by the same limitations which prevail in architecture and decoration in general; that is, that our forbears' conception of the artistic and utilitarian were so comprehensive and well adapted for the purpose that we of this date have not been able to devise any new radical types without, of necessity, absorbing some of the older ideas and changing them to suit modern conditions. However, the lighting fixtures of today, both gas and electric, are artistic and individual in a marked degree, and are not mere copies or reproductions.

It has been said by a writer that "originality in art, as in everything else, is an affair both of individual endowment and thought, and of social recognition and confirmation." An affirmation of this sentiment, from the point of view of the manufacturer, is found in the numerous notable installations which abound in all sections of our country, and which surely refute the statement that he is so far in the rear. These notable examples could be reproduced in an almost endless manner by sundry changes in detail and treatment, and to the satisfaction of the producer, architect, engineer, and decorator, as well as of the user. All can enjoy the delight of having specially designed fixtures which display originality in conception and execution, provided a sufficient sum of money is allotted to produce the desired result.

Until within a comparatively recent period the question of the lighting fixtures was almost invariably pushed aside until the building was nearly completed or ready for occupancy; then it was often found that the estimated cost of the building had already been exceeded, on account of various changes being made as the work progressed, and then the dictum given to the fixture man was that economy had to be exercised.

This statement may seem to be a liberal one, but reflection will enable one to discern that herein is the probable reason for a large number of the incongruous installations we see. In many instances, there have been sums of money spent for fine decora-

tions, often running into hundreds of dollars for a room, and more often than not the entire artistic effect is at least marred, if not spoiled, by the use of improper fixtures. The lamps will provide sufficient light, it is true, but the fixtures do not carry out the harmony, and a discord, so to say, is produced, caused by an outlay for the lighting fixtures of from one-fiftieth to perhaps one-twentieth of the cost of the decorating.

All fixtures should be in harmony with their surroundings, whether in the home or public places, and failure to observe this requirement is a fruitful source of disappointment. They should be given the same consideration and thought as any other detail of the general plan, and the more this fact is emphasized and practiced the sooner the desire of the expert for greater improvement will be realized.

If we are dissatisfied with the papering or decorating of a room, as soon as practicable we have it changed, but in innumerable instances the old fixtures are permitted to remain without even being refinished.

The selection of the means of producing light depends upon local conditions and individual taste, and must, therefore, be left to the user. Whatever the means may be, we think the best results of illumination are to be attained by the use of a fixture or chandelier supplemented by the side brackets in some of the more important locations; in small and unimportant rooms the simple side bracket alone is usually sufficient. Aside from trade reasons, the use of the central fixture or chandelier seems to be the most logical one, as by no other means can the average room be more evenly illuminated. If side brackets alone are employed, then the immediate vicinity of the lighted bracket is practically the only space favored, unless each wall is equipped with a sufficient number of brackets, the effect being surely one of lights and shadows.

The best manner of lighting a church or a hall, rectangular or square in shape, and not broken by a balcony or gallery on the sides, is by the use of fixtures on both sides of a central line, so hung that each one becomes a center of light distribution. If the church should contain a balcony, then it would probably be expedient to have a large central fixture and side brackets on the face of the balcony and on the walls beneath it.

For rooms with low and panelled ceilings, where electricity can be obtained, the use of fixtures which can be placed close to the ceiling is to be recommended. If gas alone is the medium of light, the fixture necessarily must have a longer central stem; the numerous styles of inverted burners, however, permit the use of types of fixtures which a few years ago were not thought of.

It is a fact that modern artificial light sources are too bright to be used uncovered. Where the light is to be used for a careful vision, such as reading or writing, the lamps should be enclosed in globes or shades, which will diffuse the light and at the same time protect the eye from the direct glare.

In the lighting of the house we cannot conceive a more generally satisfactory method than the use of a central fixture, and, in addition, side brackets if needed. In the home, where we expect comfort not elsewhere obtainable, the matter of light becomes one of convenience and concern. If the house is a suburban one it has a porch which serves one of two purposes: a sheltered entrance to the house, or an open-air sitting room. The lighting, therefore, should be designed in accordance with the purpose which the porch is to serve.

In the vestibule or entrance hall a hanging lantern or ceiling pendant, properly shaded or globed so as to give a comparatively dim light, is all that is required. In the reception hall there should be the tasteful chandelier, and if the hall be of the so-called "Dutch" type, with its inviting fire-place, the most natural locations for the brackets are on either side of it. For the reception room a central fixture is usually sufficient. For the parlor or drawing rooms a central fixture and side brackets; if the room is sufficiently large, two fixtures can be used without detracting from the decorations, and in this manner remove any objections to the excessive number of burners or lamps at one central point which would otherwise be required to properly light it. The lighting of a parlor, or of a reception or drawing room, should be sufficiently brilliant to bring out the full effect of the furnishings of the room and the costumes of the occupants, and still be as free as possible from dazzling spots and deep shadows. In the dining room and library, more than in any other part of the home, is the value of a central fixture demonstrated. In each of these places it is essential that the table receive the major portion of the light, and yet the source of light should be hidden

as much as possible; for this purpose no better type of fixture could be employed than the dome with its central lamp and additional arms on the outside should a general light, more than would be diffused by the central dome, be required.

Art glass, in its almost infinite variety of colors, lending itself as it does to any color scheme, has lately been supplemented and to a great extent supplanted by the ground glass, with cuttings and etchings, reproductions in a modern way of shades and shields of the so-called "Colonial" period, which are particularly effective in accentuating the delicate tints of the decorations and furnishings.

In the bed-rooms a general daintiness in the treatment of the fixtures should be prerequisite, and a fixture suspended from the ceiling and side brackets at a point in the room which would most naturally be selected for the location of a dressing table or bureau are the most effective means of illumination. Great care should be employed in the location of the outlets in these rooms; they should be removed to a distance far enough away from windows so that there may be no danger of a fire caused by a lace curtain being blown into an open gas flame.

For a bath-room two side brackets are the most desirable, and they will be found to be convenient adjuncts, as in the majority of bath-rooms the space at hand is very limited, and a fixture suspended from the ceiling is often in the way.

The "den" or smoking room is essentially one where fancy, comfort and individuality take precedence over conventionality, and the main point to be kept in mind is to secure a soft, warm light, one which will prove its companionableness in much the same silent and sympathetic manner that a good book does.

For lighting a billiard or pool table a chandelier with the lamps in a line with the long axis of the table is the most efficient. The lamps, of course, must be so shaded as to be entirely out of the field of vision and cast no perceptible shadows on the table.

The proper lighting of a bowling alley was for a long time a nightmare to contractors, but this has now been happily overcome by the use of a sufficient number of pendant fixtures and curved reflectors or shades, which apparently have remedied the former troubles.

In conclusion, the writer begs to express the hope that these remarks from a manufacturer's point of view be not considered

as arbitrary or unalterable, but only the expression of an individual opinion. As a result of the intelligent co-operation of the manufacturers with the illuminating engineer, who has already accomplished so much in the very few years he has been engaged as a specialist, we should look forward to the time in the very near future when many of the faults and evils heretofore existing, and for which the fixture man was held accountable, will have disappeared.

MODERN METHODS OF ILLUMINATION, FROM THE ARCHITECTURAL STANDPOINT.*

By Horace W. Castor.

This is a day of specializing, and we have learned the truthfulness of the adage: "A Jack of all trades and master of none." An architect no longer tries to master the intricacies of all the special branches of work entering into the completion of the buildings. It is true he is the master mind in the entire undertaking, but men who have made heating, electric work, etc., subjects of special study are called in as consulting engineers, and by the exchange of views and co-operation more satisfactory results are obtained.

I know of no set rule applicable to the lighting of all classes of buildings. Each building must have its own study, and the peculiar purpose for which the building is intended decides the form of lighting. Buildings are erected for manufacture, for shelter, for workshop, to make mirth in, to be taught in, etc., and each demands its own particular method of lighting. The lighting scheme must not be paramount to all else, but the lighting must be done without attracting particular attention to itself; it must be simply a means to an end.

Over-elaboration is harmful. The beauty of structural projections, the reveals, the cornices, the mouldings, the mass, the grouping, all these must be maintained and the lighting so arranged that these features are not lessened or made subordinate. The adaptability and construction of a building are all vastly more important than its ornamentation; so the lighting of a building for the comfort of its occupants should receive first consideration, rather than lighting for ornamentation or display. Service first and ornamentation second is good practice. As an example, let me cite the State Auditor's room at Harrisburg. Visit that room and you will see very elaborate fixtures that cost thousands of dollars, more than overdone in design, suspended from the ceiling. Directly beneath one of the fixtures is a desk intended for writing, and in order to make it adaptable for the use intended

* Read before the Philadelphia Section March 20, 1908.

it was necessary to furnish a socket and cord from this elaborate fixture to an ordinary stock green shade lamp placed on the desk, and probably worth less than two dollars, but accomplishing the purpose that the elaborate fixture did not; and remember the room was intended for a writing and reading room, and not for a show room in which to display costly fixtures.

It is the tendency now to get away from the elaborate chandelier display. The designs are simple, good lines are maintained, and outlets are so located as to avoid shadows from the fixtures themselves. In the magnificent Memorial Hall at the Naval Academy, Mr. Flagg, the architect, has depended entirely on side and ceiling lighting.

Church work affords a good opportunity for the combined efforts of the skill of the architect and the illuminating engineer. There are two suggestions for the proper lay-out for church lighting: 1. Avoid the suspending of chandeliers from trusses if their arrangement interferes with the sight line and the acoustics. 2. Avoid too much ceiling illumination, and arrange the lighting in such series that proper control before and during service may be obtained.

Chandeliers suspended from trusses, unless they are extremely well designed and of proper materials, are mostly mere conveniences on which to hang electric lamps and the dust of ages. The distance from the truss to the right height from the floor for the chandelier to hang to give the necessary light often requires a long stem. This stem looks so slender in proportion to all around it that one is inclined to muse and to count the moments when the slender stem, like the thread which suspended the sword of Damocles, would snap and cause consternation, if not decapitation, among the worshipers.

Lines of lamps used along members of the trusses do not always give satisfactory results. The trusses are usually from 50 to 60 feet above the level of the floor, and the panels, of either wood or plaster, forming the ceiling, are consequently in the glow of the light of the trusses, with the result that any defects in workmanship, cracks and dust are plainly visible from below, while the space nearer the floor, which should be lighter, is in shadow. If the design of the roof is a clere story, a satisfactory scheme of lighting is obtained by studding lamps parallel with the axis of the church, using the structural projections of the cornice

or mouldings, and as these mouldings or cornices are nearer to the floor than the line of the trusses, the light is better diffused where required, while the loft of the church, or the ceiling portion, is left in an afterglow, with all of the structural projections, cornices, mouldings, tracery, etc., left unaffected by the otherwise strong glow of light. The side walls, under and above galleries, are logical places at which to locate brackets with the lamps grouped on the fixtures. The front of the gallery, where clere story roof is not used, affords a good place for lamps, either studded or grouped. In this case, supplementary lighting will be found necessary to dispel the darkness at the ceiling, but then only in sufficient power to outline the roof trusses, etc., and bring out the effect of the mass rather than the detail.

The chancel of the church, with its altar, its reredos and costly and beautiful fittings, requires a great glow of diffused or reflected light, rather than individual lamps. All things else in a church are tributary to the altar. It is the very centre of life, the sun at high meridian, the soul of the entire organism, therefore, all lighting outside of the chancel, which contains the altar, should be subordinate to the lighting of the chancel. Our thought in having all lamps controlled in succession is to accentuate the effect of the chancel lighting. For instance, the church just before opening services should be light and inviting. God never intended us to be creatures of darkness. The full burst of light in the chancel, obtained by concealed continuous reflectors with lamps on the back line of the arch and jambs, should be on, and as the moment for service approaches certain series of lamps in the church, but not in the chancel, should be gradually cut out, without attracting special attention, but the glory of the light in the chancel should remain through the entire service. These suggestions may be well enough if the instructions are followed by those in charge, but unfortunately this is not always the case.

I have failed to see in any of the standard works on church architecture any special discussion on the lighting of churches, and it is not my purpose at this time to take up the question as to how to arrive at the proper number of lamps to give the required effect in church work, but I want to cite an instance which may argue to the advantage of the architect and the illuminating engineer, frequently consulting for this class of work.

Experience in lighting of churches has been mostly obtained by observing actual effects and improving the arrangement, if occasion demand, in later work. We must have obtained approximately the proper solution of the lighting problem, as the following incident will show:

Some years ago we laid out the lighting for the St. Paul's Reformed P. E. Church, and recently we asked your Mr. Calvert to supervise the electric portion for us in a church which has just been finished and is similar in design to St. Paul's. It may be of interest to you to note the proportions existing between the two churches:

In St. Paul's Church.
1 lamp to 740 cubic feet.
1 lamp to 27 square feet.
In the Chancel.
1 lamp to 135 cubic feet.
1 lamp to 4 square feet.
Mr. Calvert's Figures.
1 lamp to 740 cubic feet.
1 lamp to 30 square feet.
In the Chancel.
1 lamp to 152 cubic feet.
1 lamp to 6 square feet.

In some churches the illumination of leaded glass windows at night to give effect from the inside can be done with pleasing results. In New York City there is a church which stands on a corner, having sunlight on one side, and a party-wall on the other side. The architect placed leaded glass windows on the party-wall side to correspond with the street windows, and to give the effect of daylight he introduced electric lamps concealed in the tracery of the windows. While these windows on the party-wall side are illuminated only during the day, there is no reason why if the same scheme is followed pleasing interior effects cannot be obtained at night, if the leaded glass windows are illuminated. The Renaissance Hall in the Masonic Temple is an illustration of the above suggestion.

The illumination of factory buildings or manufacturing plants resolves itself into a commercial proposition rather than one calling for the skill of the architect. Depending upon local requirements, a plant may be lighted with high efficiency units

for general illumination and separate lamps be provided for separate pieces of machinery, or there can be no separate lighting for machinery, but an increased general illumination which will be suitable for all requirements.

School-houses, banking institutions and buildings of public assembly, etc., each has its individual requirements. Theatres, as far as illumination is concerned, are as a world unto themselves. We look for the aesthetic, pleasing details, warm bright coloring and all that appeal to the enjoyment of mind, and nothing adds so much to that enjoyment as liberal decorative illumination. A well-designed church is not dependent for its impressiveness upon decorative or ornamental illumination, but these embellishments add essentially to the pleasing effects of theatres.

It was not until the World's Fair at Chicago that the possibilities of exterior decorative illumination were appreciated, and since then exterior illumination or illumination of fair or exposition buildings has been one of the features strongly emphasized. The effects are made possible from the fact that the buildings in question are designed mostly along good classic lines, giving to the illuminating engineer an ideal skeleton upon which to work. For this class of work the essential or major structural portions of the buildings, and not the lesser projections, should be illuminated.

If possible, the reveals, or such portions of the building indicative of strength, should be maintained. If an arch is outlined, don't let it float, but outline the "reason" for the arch. If the cornice is illuminated arrange for reflected light, if possible, to show the projection of the cornice, rather than to emphasize any of the members or consoles of the cornice, and if the roof is pitched and is a part of the design of the building, then outline the roof so as to convey to the mind the proportion of the building as seen by sunlight. If the corners and principal outlines of the building are illuminated by a higher candle power and the details and lesser parts of the building by a lower candlepower, a most pleasing effect is obtained.

One of the striking features of the illumination at the Jamestown Exposition was the strongly marked horizontal lines and the absence of meaningless festooning of strings of lamps.

A knowledge of the point of view is essential for proper illumination. That is, if the building is located on a narrow street and a view of the building is limited to the width of the street, the lower portion of the building, which is in direct line of vision, and which mostly contains more details than the upper portion of the building, should be illuminated to a greater degree, with more attention paid to the reflected light and direct lighting than to the upper portion of the building, where direct outlining will usually suffice. But if the building is located at a fair or exposition, so that one can grasp the entire building, and it will be viewed at close quarters as well as at a distance, then the whole structure can be treated and studied for the effect of direct and reflected lighting.

It was well worth a trip to Jamestown, if for nothing else, to see the effect of the illumination at close range, and then at a distance. As the darkness of the evening approached, robbing the buildings of their finer details and leaving only the structural portions in evidence, there appeared here and there little flashes of light like the sparks from a white hot iron under the blows of the blacksmith's hammer. The flashes continued to increase in numbers until series after series were thrown on, and the seeming little sparks were united into one immense fairy chain of light, as if trying to tug back the light of day. When the electric lamps, with the ever watchful searchlight keeping tab on the thousands of incandescent lamps, which were as links in the chain of illumination, lost their individuality and became as bands of light, the details of the building vanished and there was nothing left but the strong structural outlines of the buildings resting apparently on nothing more substantial than the dancing water, we were more impressed than ever with the very satisfactory results obtained by the combined efforts of the architect, who knows less of electrical illumination and more of architecture, and the illuminating engineer, who knows more of illumination and less of architecture.

DISCUSSION OF MR. CASTOR'S PAPER BY THE PHILADELPHIA SECTION.

Mr. H. Calvert.—The illumination of churches does frequently present serious problems. The lamps are often placed so that the light will shine directly into the eyes of the congregation in the main body of the church, and also into the eyes of the audience in the galleries, and the fixtures from the ceiling may or may not be in the line of vision of the altar.

In the church referred to by Mr. Castor a row of lamps was put on the outer edge of the gallery. The illumination was determined entirely on the basis of candle feet, and it was purely a coincidence that the figures as to the number of lamps, compared to the cubic and square feet, came out so nearly as Mr. Castor has stated. In this case the amount of illumination required in the main body of the church was calculated to be in the neighborhood of one candle-foot per square foot of illuminating surface.

Mr. Henry D'Olier, Jr.—One of the most peculiar propositions in dealing with church lighting relates to the people who worship in the churches. I have in mind one place where, after the chancel of the church was well illuminated and the chandelier was still allowed to remain for test purposes, although four laymen out of five who witnessed the test were satisfied with the general appearance of the illumination put in, they were still satisfied with the gas light that issued from the chandelier. When that was extinguished, and the effect of the concealed lamps was seen, the people seemed to think there was very much less light, and expressed a great deal of dissatisfaction; upon individual tests, such as simply reading a book, each found, much to his surprise, that there was much more light. The problem of convincing the laymen is among the difficult ones to be met in church lighting.

Mr. E. G. Perrot (of Ballinger & Perrot, architects): Architects are not supposed to be engineers of illumination, and the co-operation of the illuminating engineers is one of the essentials in carrying out their schemes. One of the problems to be solved, in the designing of structures, is the lighting of churches with nave and side aisles. The proper way to light a large nave, in my opinion, is not to hang a chandelier from the apex of the

arch, but to arrange side lamps on the walls of the cleristory, or hang chandeliers from the sides of the arch. The Notre Dame at Paris is lighted in this way, and the effect of the vault of the main nave is not destroyed by a row of chandeliers down the center of the arch.

In a certain church which has a great many electric lamps, a grand effect is produced in the sanctuary by putting lamps at the back of pilasters, and although there are many lamps that can be seen, the side lamps are not visible. At the arch of the door-way that is enriched with a small portico, there is a tie rod to prevent the arch from spreading. The central part of this rod is ornamented with scroll work, or a lantern is placed in the center. Instead of this lantern there has been substituted a metal escutcheon, at the back of which is a reflector and a bulb so placed as to throw the light on the tympanum of the doorway, which is enriched with an inscription. Persons passing the building will not see the bulb, but they will see an illuminated doorway. This same scheme can be applied in many instances, and I consider it far superior to the method of employing a naked lamp.

I know of one case of the lighting of a pulpit where the design unintentionally resulted in the formation by shadows of a Maltese Cross on the soffit of the canopy. To throw light on the preacher lamps were placed in the panels in such a way that the light was thrown downwards, thus outlining the panels, the shadows forming the Maltese Cross.

Mr. C. W. Pike.—You may prove to a man mathematically or physiologically that he does not want to have glaring light that will close up the pupil of his eye, and may furnish him with a lamp equipped with a shade that will properly diffuse the light and permit of more light entering his eye without injury, and make him see things better than he did before, but you cannot always make him believe that the illumination is better than what he had previously. In one case arc lamps were well placed and provided with prismatic shades giving better effect than the lamps previously there, and yet the owner decided to employ the old methods.

One thing which might well be introduced into church lighting is dimmer lamps. There is a distinct mental strain from a sudden illumination in a room, and if one is at all nervous he

will feel himself jump when the light is suddenly increased or diminished. There is no doubt that when subdued effects are produced the effect on the audience is marked. Those of you who have been in Catholic churches and in great cathedrals have noticed what a feature is made in certain portions of the services in lighting the altar with candles.

A great many of the troubles that are noticeable in the lighting of both old and new buildings could be avoided if the lighting part of it were taken up at an earlier stage. In my experience the lighting is generally the last thing taken up. The design is made, the building is constructed, and at the last moment some fixtures are obtained in the selection of which the owner unfortunately takes an important part, and he generally goes to the warehouse of the fixture manufacturer and selects fixtures which will suit him and his wife and his grown-up daughter. His selection may not be appropriate, and the placing of the fixtures may not suit the room. The lighting equipment of the rooms should be selected just as soon as the decorative scheme of the rooms has been decided upon, and having ascertained the quantity of light necessary it should be easy to determine where the outlets are to be located. The fact remains that they are not usually so determined. It is not usually the fault of the architect, but of the owner, who will not consider where the lamps are to be put, or the kind of fixtures that would be suitable for his building.

Mr. R. L. Lloyd.—It is very objectionable to place the lamps in the range of vision of people seated in a church gallery. However, when the fixtures are fitted with extremely heavy glass, so that one cannot see the outline of the lamps inside, and yet they are put up in such numbers that the light, while sufficient, is not at all hard on the eyes of that portion of the congregation upstairs, the proper results can be obtained.

Mr. Robert C. Ely.—It seems almost essential to suspend fixtures from the ceiling of a church to give sufficient light economically. It is almost impossible to light a church sufficiently with side-bracket lamps. In one case good results were obtained by suspending the fixtures from the ceiling, and using a line of lamps on the face of the balcony on brackets high enough to give sufficient light over the sides and rear. It would have been twice as expensive to illuminate that church from the lamps in cornices.

THE RELATION OF ILLUMINATING ENGINEERING TO ARCHITECTURE, FROM THE ENGINEER'S STANDPOINT.*

By E. L. Elliott, *Member*.

According to the most plausible theory of man's descent, the original "family tree" of the whole human race actually stood in the forest, and our common ancestors disported themselves among its branches, instead of merely having their cards attached, as represented by the present day genealogists. At a subsequent time natural caves furnished shelter from the elements, and the too familiar attentions of the larger and fiercer animals. As developing intellect began to give primitive man the ascendancy over the lower orders of brutes, he began to construct shelters out of stones and boughs. These shelters were, of course, the work of the individual dweller. With the development of these rude shelters into more elaborate dwellings, their construction enlisted the co-operation of a number of individuals. Co-operation invariably requires leadership. Where the work of more than one individual is directed to a common end, there must be a director. Thus, in the evolution of building, there came a time in its very early stages when a master-builder was a necessity. The word "Architect" is merely the Greek equivalent of "Master-builder."

The fundamental purpose of the architect is thus disclosed; namely, to plan and direct the construction of a building so that as a whole it shall fulfill all the purposes for which it is intended. Herbert Spencer has shown that the aesthetic instinct took precedence over the desire for protection in the evolution of dress; and while the same law can probably not be shown in the evolution of building, it is certainly true that the desire to decorate was very nearly contemporaneous with the ability to build. Thus, almost from the beginning, building involved two theoretically distinct elements; namely, Utility and Beauty. These two elements, however, were practically connected; and thus the architect became not only the mere director of labor, but the originator and arbiter of art as applied to building.

* Read before the New York Section March 12, 1908.

In the advance of civilization it came about that structures were frequently erected in which the artistic or aesthetic elements predominated. Such buildings were intimately connected with the religion of the time, or with the government, or with both, which were generally closely allied. The aesthetic effect served an important purpose in impressing the people with the authority of their government and religious institutions. The few remaining portions of early structures of this kind, together with contemporaneous descriptions and other evidences, show that, in point of grandeur and beauty of conception, and even in the manual skill of execution, many of these structures have never been surpassed. They were wonderful embodiments of the highest degree of artistic taste and originality, coupled with the lowest form of human labor. Massive blocks of stone were quarried and hauled long distances, and fitted into their prescribed places with consummate skill, so far as the actual results were concerned; but this was accomplished with a total disregard of human life. An outline drawing found on an ancient ruin shows a huge block of stone, with scores of men pulling it along on a prepared track by means of ropes, while a single individual sits on the front of the block pouring grease upon the slide-way. Neither time nor human life spent in this unspeakable drudgery were considered.

The substitution of the force of nature for the mere brute force of the human muscles is an entirely modern achievement. The utilization of natural forces to accomplish what had hitherto required the muscular power of human beings is the foundation of modern engineering. Where the ancients piled one stone upon another, producing a result which in itself was grand and beautiful, but which required centuries of labor and the waste of innumerable human lives, modern civilization accomplishes equally great results within the space of months or days, and with no greater expenditure of brute force than the workman may exert in carrying his full dinner pail: that is engineering. Strictly speaking, there are no remnants of any ancient structures which show the application of true engineering principles; for engineering implies not only the achievement of results with the minimum of material and labor, but a degree of classified knowledge which enables the engineer to predetermine accurately the amount of any given material, and the form necessary for it to take in order to secure these results. Such knowledge belongs only to modern science.

What we term "modern civilization" is characterized by its extreme complexity as compared with ancient civilization; and this complexity is largely the result of a vastly greater knowledge of natural phenomena. In a single century we have learned more of the workings of nature than had been found out in the entire previous existence of mankind. The result of this has been twofold: It has transformed the large majority of human beings from mere engines of force into sentient creatures, who are thereby free to develop those mental powers which lift them above the animals; and as a direct consequence of this emancipation, the human family is on a vastly higher plane of intelligence and general happiness. Let those who are disposed to exalt the glories of ancient times, as shadowed forth in the few sublime efforts of human intelligence shown in ancient writings and religious temples, be reminded that what we to-day are so fond of calling the "common people" were in those past times brute laborers held in hopeless and degrading servitude. And let those who are disposed to cavil at the "materialism" of modern science be admonished that it is owing to the scientist and engineer, "materialist" though he may be, that every individual to-day is free to work out his own destiny.

Even admitting that we have less commanding geniuses in the field of art and architecture than may have existed in the palmiest days of Greece and Rome, it is indisputable that the total amount of artistic appreciation among the masses of people is incomparably greater; and it is the scientist, the engineer, that has brought this about.

This preamble may perhaps seem far from the topic proposed for discussion in this paper; but it is always well to begin with fundamentals. Furthermore, there is still a very considerable degree of feeling among modern architects that the engineer and all his works are of the earth earthy, and constitute a sort of necessary defilement of the rarified spiritual atmosphere in which they should by rights dwell. This condition was more forcibly than elegantly expressed by an architect, who said of a client who insisted upon arguing from the utilitarian standpoint, "He talks like a —— engineer." It is a matter of record that the architect has occasionally so far lost sight of this lower utilitarian plane as to omit such trifling utilities as stairways; and as the unappreciative client climbed to his bed room on a ladder placed on

the outside, we may well imagine his consigning the architect to those same regions to which the architect wished to send the too materialistic engineer.

Ancient and modern civilizations have scarcely a single important element in common, barring the elemental human passions, which never change. There is scarcely a phase of life which is not essentially different to-day from what it was in ancient or mediaeval times; and this radical difference is, and by rights ought to be, exemplified in modern building. In Greece a philosopher gathered such people as had the time and disposition to hear him beneath the shade of a tree, and expounded his doctrines. The modern counterpart of this is the University, with its millions of dollars worth of buildings and equipment, its thousands of students, and its hundred of instructors and professors. In place of the parchment scroll we have the daily newspaper, produced at the rate of several thousand complete copies a minute. These two instances give a fair measure of the all but infinite space between the old and the new. And yet the modern architect seems to have but one anchorage in which he has implicit faith, and that is his veneration for antiquity; when he casts loose from this he drifts and tosses about, and knows not whither to direct his course. He dare not discard the parchment scroll, but would have it printed on a rotary press. Appreciating the simple beauty of the monolithic column, he strives to attain it with steel beams, hollow brick, and cement. Inspired by the majesty of the gothic arch, he reproduces it in lath and plaster.

The habit of clinging to past forms of architectural expression is not infrequently carried to the point where it becomes ludicrous. The wind-swept island of Great Britain naturally developed a type of cottage having long stretches of sloping roof, designed to keep the whole structure as near to the ground as possible. As this developed in the very early period of the art of glass making, the windows of necessity were divided into a large number of small panes. Incredible as it may seem, one of the first so-called "sky-scrapers" to be erected in New York was modeled after this type of cottage. The building is still standing at No. 1 Broadway, and has the distinction of being the only "Queen Anne" office building in the metropolis. On the other hand, the pointed arch, the succession of long vertical lines, and the versatility of adornment, which are the basis of gothic ar-

chitecture, and which would lend themselves to modern building with comparatively little violence to the original spirit of conception, have been only recently attempted, and then only in a timid and half-hearted manner. But even this one cautious attempt has resulted in the most beautiful facade of any office building in the city, as will be seen by observing the Trinity Building from the south.

Eliminate the features borrowed from ancient and mediaeval buildings and what have we left to represent modern architecture? In public structures, only what is often well expressed as the "dry goods box" type, of which examples are too numerous to mention; and in private residences, what Lawson has picturesquely characterized as "pastry cook's nightmare, in bronze and marble."

The simple truth is that modern civilization has not yet expressed itself in architecture. Were our nation to be suddenly blotted out to-day, the structures which would most adequately portrays its habits of life and planes of thought would be our engineering works—our bridges and tunnels, our railways, mills and factories. In point of beauty some of our modern bridges may be put along with any architectural structure of antiquity. True, the beauty is of quite a different type; but so was beauty of person of a different type in ancient times.

Reduced to its lowest terms, the business of the engineer is to produce a given physical result with the minimum of material and labor; and the justification for his vocation must be found in the extent to which he can accomplish this end. Emerson has defined beauty, taken, of course, in its physical or material sense, as "that which has no superfluous parts, which exactly fulfills its purpose." In following this definition the work of the engineer is beautiful to exactly the degree that it is efficiently done.

Broadly speaking, the modern building is simply an aggregation of utilities. With very few exceptions it is simply a part of a vast machine; a machine being properly defined as any device which enables man to accomplish more or better work than he could do without it. Apply this at random and see how well it fits. The factory building exists because it enables work to be done that could not be done at all in the dwelling, or that can be done to better advantage; and it is as much a fundamental part of the apparatus for producing the particular articles made as is

the engine or machinery. So the office building is merely a device by which the various operations of accounting and communication can be efficiently carried on; and so with the store, the school house, and to a large extent, even the dwelling. Almost the single exception is the church; and this, from being almost the only form of public building, has become a comparatively infrequent and inconspicuous structure.

Building to-day has, therefore, become almost entirely an engineering problem; and with the vast increase in the complexity of life which characterizes modern civilization, has arisen the necessity of subdividing the general problem of construction into a number of distinct branches. Among these are the purely mechanical construction, which has given rise to structural engineering; methods of heating and ventilating, with its special engineering; electrical equipment, with its electrical engineering; provisions for sanitation, with its sanitary engineering; and lastly, the necessities for artificial illumination, demanding illuminating engineering. All but the last mentioned of these special branches of engineering have gradually been necessitated in the evolution of building, and have been accepted by both architect and client. It is only the last that is still to some extent in the undeveloped state.

Accepting the formula already given as to the general field of engineering, we arrive at the fundamental proposition that the business of the illuminating engineer is to produce a given or required result of illumination at the minimum outlay for the original installation, and subsequent maintenance cost. This leaves one highly important question still to be settled; namely, who shall determine what the required illumination shall be? Evidently this question must be decided jointly or separately by the three parties to the contract; namely, the owner or client, the architect, and the illuminating engineer. It may be stated without fear of serious contradiction that the owner has fully met his responsibility in the premises when he has clearly set forth the exact uses for which the various parts of the structure are to be put. It then lies between the architect and the illuminating engineer to determine what the best illumination for each and every particular case may be. As between these two parties, the greater economy of thought and labor will be secured by placing the responsibility upon the illuminating engineer. To determine just what manner of illumination is best for all the numerous

and widely varying conditions of modern life requires an extent of technical knowledge, and a breadth of experience which the architect may very appropriately and wisely avoid, providing the results can be obtained from other sources. It is simply a matter of division of labor and economy of human effort. Modern civilization demands that the individual shall be able to do some one thing completely and well, and shall not spend his time in doing things which he can only do indifferently, and which others can do more efficiently.

Benjamin Franklin used to set his own writings in type, put them in the press, and take a hand in running off the printed sheets; and even Horace Greeley was in the habit of going to the cases and setting up his own editorial in his early days; but this was not true economy of human effort. There was many a one who would have been glad of the job of setting the type, whose written productions would have been of infinitesimal value. Surely the architect of to-day has a sufficiently wide and dignified field for his labor in the legitimate work of unifying and harmonizing all the diversified elements that enter into a building, without bothering his head about the infinite details of these different elements.

The advent of the illuminating engineer as a specialist should be hailed with greater delight and relief by the architect than by any other member of the community. Having satisfied himself of the competency of the illuminating engineer, just as he would satisfy himself of the competency of the electrical, or construction engineer, the architect can turn over the plans of the building, with the specifications of the use or uses to which it is to be put, and probably also a statement of the illuminant to be used, and leave the entire technical problem to the illuminating engineer. On the other hand, the illuminating engineer must have authority commensurate with his responsibility. The architect would not think of arbitrarily changing the specifications of a structural engineer without his full consent, and for the same reason the plans of the illuminating engineer should be equally respected.

There is one difference, however, between these two branches of engineering as connected with building; the skeleton of a building, which is the work of the structural engineer, is hidden when the work is completed; but the apparatus especially connected with the illumination is not only in plain view, but so conspicu-

ously in sight as to form one of the necessary elements in the artistic whole. This phase of the problem of illumination therefore, falls within the legitimate province of the architect. There is clearly but one solution of this apparent clash of authority, and that is co-operation between the architect and the engineer. The engineer demands a certain physical result; the architect demands certain structural features or conditions in order to produce the general harmony of result which it is his business to secure: how shall these two demands be reconciled? Evidently there will be a large number of cases in which no reconciliation will be necessary; all that is required will be such a versatility on the part of the engineer that he can design the physical part of the installation so that it will produce both the physical and artistic results demanded. It is conceivable, however, that cases may arise in which the artistic conditions required by the architect can be secured only at a greater or less sacrifice in economy: the decision then very clearly rests with the client. The possibility also still remains of the architect specifying certain conditions which he considers essential from the artistic standpoint, but which the engineer deems not only uneconomical, but positively detrimental in point of the resulting illumination: who then shall decide? In this as in all other cases, the client is the court of last resort, on the generally accepted theory that he who buys an article has a right to dictate as to its character. If a man chooses to work by light which is dangerous to his eyes, or is ill-suited to the purpose for which the illumination is required, for the sake of the supposed artistic effect, he can hardly be denied his right to such a course, however foolish it may seem to the engineer. Such cases, however, are hardly likely to occur under proper conditions. There are few persons who would willingly subject their eyes to a dangerous strain, or handicap the efforts of themselves or their employes by bad light after having been duly warned.

Since the larger proportion of buildings at the present time are predominantly utilitarian, there is extremely little opportunity for any disagreement between the illuminating engineer and the architect. In all this large majority of buildings the general artistic talent of the illuminating engineer should be sufficient to avoid such breaches of taste as would be objectionable. This class of building includes factories of every description, office buildings, school houses, and the larger portions of hotels

and public buildings. In the case of a large number of residences the illuminating engineer should also be competent to lay out, or pass upon every feature of the installation. There remain then only the more pretentious class of dwelling houses, churches, theatres, and to a partial extent libraries and public buildings, in which co-operation of engineer and architect is essential. In these cases the artistic features of the lighting installation are of such importance as properly and justly to demand the attention of the architect. However, while the architect is properly the arbiter in such cases as to the artistic side of the problem, the services of the illuminating engineer are no less valuable than in the other cases. Let it be clearly understood that art as applied to architecture does not exist for its own sake, but is only directed to the embellishment of the necessary and essential physical features of the building. Good decorative art is not only compatible with an efficient physical result, but can be considered of the highest order only when it conforms to good mechanics—in fact, decorative art rests upon a purely scientific basis.

A careful analysis of the respective provinces of the illuminating engineer and the architect, therefore, discloses no more ground for mutual disagreement and distrust than between the architect and any other engineering specialist. The passive or active antipathy which has thus far existed to a greater or less extent on the part of the architect toward illuminating engineering, appears to be wholly unjustifiable; and it may be worth while to seek the reasons for this apparently groundless opposition. The most obvious cause of this feeling may undoubtedly be found in the fact that the illuminating engineer has thus far been to a large extent a reformer; in fact, the very existence of his profession may be directly traced to the prevalence of bad practice in the use of light. The faults of illuminating installations as designed under past conditions at last became so numerous and so obvious that there arose a demand for reform. It was hardly to be expected that those who had perpetrated the outrages would themselves turn about and reform their own works. The reform had to be through the agency of independent individuals who had made a particular study of the special conditions needing the reform. It is also to be expected that those responsible for malpractice will defend themselves and their works with all their energy, until they are convinced of the futility of such a

course. The work of the illuminating engineer thus far has, therefore, been necessarily directed to a large extent toward pointing out the faults of the prevailing practice. Such a course is by no means the most agreeable of tasks, but is a necessary preliminary to better work in the future; and the illuminating engineer must not shrink from this task until the absolute soundness of his contention has been universally recognized.

In most cases the sins of the architect have been rather of omission than commission. With the increasing demands upon his attention from the growing complexity of building, he has given less and less attention to details, and seemingly the least attention of all to the extremely important matter of artificial illumination. Lighting systems have been put in either without the slightest regard to the scientific principles involved, or at best with the aid of a few rule-of-thumb formulas which were as apt to produce faults as anything else. Only the greater ignorance of the client has prevented an earlier upheaval. Were proportionately serious mistakes made in other points of construction, there is scarcely one building out of ten that would be accepted by the owner when completed. What would one say, for example, on learning that the heating apparatus in his building was wasting 25 per cent. or even 50 per cent. of the fuel? And yet such losses in light are by no means uncommon.

Perhaps from a natural inclination to avoid details, the architect has very frequently delegated his duties to the fixture manufacturer, with the result always to be expected when the blind leads the blind—namely, that they have both fallen. The sins of omission committed by the architect were even surpassed by the sins of commission committed by the fixture maker. Where the architect specified a number of light-sources, figuring in a vague way on the illumination which they would produce if unobstructed, the fixture manufacturer has perhaps reduced the illumination to one-half by the accessories and construction used. It is quite to be expected, therefore, that the fixture manufacturer should not welcome the illuminating engineer with open arms. It is bad enough to have one's faults baldly pointed out; but when such faults have been an important source of revenue, the sting is so much the keener; and there is no denying the fact that a very considerable part of the faults of lighting fixtures are directly traceable to a desire for profit.

Recently a lighting installation in a public building caused

a political scandal, owing primarily to the discovery of the fact that the fixtures had been sold to the State by the pound; or more properly speaking, by the ton. But it was rather the fact that the interested parties had overreached themselves, than in the method of computing values, that constituted the novelty of the crime. As a matter of actual fact, there are any number of cases in which the real or apparent weight is the actual basis of value. Look at any fixture you please, and judge for yourself how much of the metal work is essential, and how much is a mere excrescence hanging on in the name of art, but having its true motive in the pocketbook. It is the existence of this condition of affairs that has made it necessary for the illuminating engineer to give a greater consideration to the artistic side of their subject than ideal conditions would require or justify; and so long as the condition prevails their efforts must continue.

The architect has had the reins from the beginning of history to the present time, and must be held wholly responsible for the results. If these are faulty, there need be no hedging on nice distinctions as to exactly whose duty it may be to institute the reform. The reformer is justified by his works.

The principal point in dispute thus far between the illuminating engineer and the architect seems to be a question of jurisdiction. The architect has been comparatively ready to admit the authority of the illuminating engineer in regard to the purely physical and economical aspects of the question, but has denied his authority in matters pertaining to the aesthetic or decorative features involved. The engineer, on the other hand, has contended that under this ruling the architect can practically overthrow the results of his labor by setting up the claim of æsthetic requirements. On the general principle that "he who seeks equity must come with clean hands," the illuminating engineer is disposed to hold up the examples of architectural aberrations, which are so conspicuously numerous, as an answer to the implied charge that he is incompetent to form a correct judgment in matters of art. So long as such architectural monstrosities as the New York Custom House, for example, continue to obtrude themselves on a helpless public, illuminating engineers will not be disposed to yield too readily to assumptions of artistic superiority on the part of architects.

Since illuminating engineering involves questions of decorative art there is no reason why the illuminating engineer should

not make a sufficient study of this side of his profession to become an adept. The principles of art as applied to architecture are within the grasp of any intelligent person having a reasonable amount of native appreciation, and there is no more reason why the illuminating engineer should not master these principles, at least so far as they affect his profession, than there is for the architect not acquiring the general principles of structural engineering.

Whatever his incompetency may be in regard to the purely artistic side of the question, there is one invaluable result that is sure to follow the agitation that has been set up, and that is a greater amount of attention on the part of both professional and layman to the subject of illumination. The results in this regard are already apparent. The very first essential to reform is to discover the need of it, and until this discovery is made and accepted by a sufficient number of the people it is useless to look for improvement. The fact that the former prevailing practice in lighting had numerous and grievous faults is becoming pretty generally known, and as a direct result of this knowledge a demand for better methods is making itself felt. Let us welcome the results, and be duly grateful to the agencies through which they were brought about.

DISCUSSION OF MR. ELLIOTT'S PAPER BY THE NEW YORK SECTION.

Mr. Bassett Jones, Jr.—If the illuminating engineer is to raise himself to the station he hopes to attain he must stop pluming himself on his "good taste" and get to work learning what good taste is. He must create his own aesthetic environment—study his architecture and become familiar with the fine arts. For beauty is the same all the world over, and its highest form is not found in practical application but in the abstract.

The author strives to narrow the field of beauty to the limits of mechanical construction, which is, perhaps, natural and, from his point of view, inevitable. This is a mechanical age. We think and live in an atmosphere redolent with the odor of engine oil, so that art, which must be expressive of the ideals of its age, tends to assume a spirit of nervous activity; in other words, it becomes "busy." It tends to lose that element of repose which

has been considered one of its most desirable attributes, and so perhaps takes one more step in that downward movement which began with the decline of the Renaissance. This "busyness," this appearance of mediocre subjects so evidently bent upon a purpose, this fussyness and insignificance, should be a warning to us, for our appreciation is distracted by this very purposiveness, and the actual elements of beauty in the composition fail in sensuous appeal without which beauty cannot be said to exist.

Objects of practical utility, such as lighting fixtures, in so far as they claim to be within the realms of beauty, make two demands upon our attention: (1) That they actually do what is demanded of them as lighting fixtures—that they fulfill a practical purpose; and (2) that they achieve this end in a smooth and harmonious manner. A straight gas jet of plain pipe, efficient in mechanical design and construction, can give light just as readily, and with as much if not more economy of energy than the most elaborate French fixture. It absolutely fulfills the demands of practical utility and economy, yet it will probably be ugly to a degree, and its annoyance from this defect may well offset its practical usefulness. The eye finds absolutely no immediate pleasure in observing its form. Its sharp angles and the lack of harmonic relations between its members produce a painful, repulsive reaction. So we seek to modify its shape, its form, its proportion until we find that the mere sight of the fixture gives us pleasure apart from any reflection as to its meaning as a manufactured article. It now fulfills a purpose which is one with its own being and is fundamental—even deeper than that which gave rise to its mechanical form. This purpose, "to prolong pleasurable stimuli, is the foundation of all organic activities." The mind of the beholder is now free to ask, "what is the thing for?" A question that would not naturally arise unless pleasure rather than pain was felt in the mere presence of the object.

I trust that I have made it clear that we cannot judge of the aesthetic worth of an object merely by considering adaptability of form to purpose. On the contrary, we can, I think, agree with Ruskin that repose is fundamental in the scale of beauty, if fundamental there be, for the smoothness and readiness with which the sense stimulations are assimilated will surely determine whether attraction or repulsion shall be dominant in the perception of the object.

The author would add efficiency to the elements of beauty. He asks us to believe that "the work of the engineer is beautiful to exactly the degree that it is efficiently done." The difficulty would be that beauty being a spiritual or ideal quality must find in the mental processes a parallel for each of its elements, and it is not clear just what process shall represent efficiency as such. I should be disposed to admit, however, that economy, given its fullest meaning, may be at least a secondary attribute of beauty. But in this case we must be careful not to confine economy to the dollars and cents, or purely materialistic aspect, which is the usual meaning given to the word by engineers.

It must not be understood that we can abstract beauty from the concrete. Beauty is no "ding an' sich." It is not even an idea. It is rather the form of the idea fundamentally pleasurable in perception, and at the same time, more than pleasurable.

Mr. Elliott has made a very evident atempt to outline a scheme of procedure based upon what he considers to be the nature of architecture, and I doubt if we can appreciate the value of his viewpoint short of a very careful analysis of some of his opinions. The subject is very difficult to understand, however, and we may very readily get beyond our depth. The point I hope to make clear is that "good taste" cannot be based upon whim, fancy, or prejudice, but must be founded in a synthetical judgment, thoroughly trained, both in abstract and practical reason—an aesthetic necessity that was first formulated by Kant in "The Critique of the Power of Judgment."

Beauty is compounded of many qualities, which it goes without saying, are almost, if not entirely, lacking in the vast majority of modern utilitarian constructions. It cannot be doubted, however, that the spirit is but dormant, and only requires the disturbance of a mental precipitation and a social revolution to rouse it from its lethargy.

The author tells us that there "are no remnants of any ancient structures which show the application of true engineering principles." Think of the Pantheon with its wonderful discharging arches and its dome illustrating a thorough and complete knowledge on the part of the builders of the principles of statics! What is the Parthenon but a perfect example of flat arc construction? Would not any engineer of today think twice before he would undertake the erection of such a living, moving, delicately

articulated embodiment of the laws of arch forms as La Notre Dame de Paris? Were these universally perfect results attained haphazard, think you? No more so than the aesthetic ideals of the times were not carefully and expressively wrought into every detail. We admit that no treatise on statics had in those days been written, but even today do we not sometimes trust to our feeling for right construction and proportion and to our experience of what certain structural combinations will and can do? Well, imagine this feeling, trained to extreme delicacy by a life of actual practical working with stone and wood. Does not the text book become almost a superfluity? And what is modern technical education but largely a substitute for these years of practical training—a short-cut, so to speak, to everything but judgment, which comes, if at all, only with gray hairs, and has not been and cannot be included in any technical school curiculum.

It is rather amusing to hear the readiness with which some modern engineers cavil and sneer at the engineering ability of the ancients, but I have yet to hear of a scoffer who has actually measured, scaled, and checked one of these old structures. The only two authorities with whom I am familiar who have actually taken this trouble before announcing their verdict are M. Viollet le Duc and Sir Benjamin Baker, and both of these renowned engineers are unstinted in their praise of the accuracy and precision with which, as a rule, the construction of historic buildings was designed. It is not necessary that the description of our experience be expressed in mathematical form before it becomes "true engineering principles." The principle is true by whatever symbols it is represented. Its concrete embodiment is the measure of its accuracy.

Mr. Elliott is hard on the architects, and I think we can admit that many architects are only architects in name and not in ability. But when he undertakes to generalize from isolated cases we must draw the line and ask whether it is not possible that on occasions engineers have also been lax in their duties. Surely we all know of cases where frightful loss of life and great destruction of property has been caused by careless design and equally careless inspection.

In the attempt to lay all the benefits of modern society at the door of the scientist and engineer the author forgets that

causation is continuous. We have always understood that it was the schoolmen and philosophers of the middle ages who, in clearing the world of dogmatic rubbish, re-established the continuity of development, begun in ancient Greece, and made it possible for science to regain its foothold.

Taking the wording at its face value, I agree with most of what Mr. Elliott says regarding illumination. It is "a required result of illumination" that the engineer must produce at a minimum outlay for that particular "required" result, and not some other result determined by the engineer. The duty of the architect is that of "unifying and harmonizing" lighting fixtures with their environment, and light with the architectural treatment. Thus he determines the "required result" which the engineer must achieve.

Even admitting that the definition of the beautiful is wider today than it has ever been before, yet it is idle to talk of a future art based upon the spirit of modern mechanical aesthetic genius. The influence of science on the modern aesthetic consciousness is due to the broadening and deepening of the intellectual imagination rather than in any direct modification or shifting of the aesthetic medium. The work of art must remain devoted in the future, as it has been in the past, to the creation of an ideal world in which all the elements of human thought are expressed as a concrete representation of the union of reason and feeling. Its subject will always be the form of the human consciousness distinct from the form of nature, but embodied in nature as the individual representation of man's interpretation of the meaning of the world of reality. "The principle of art is the significant. The result of successful treatment is beauty."

Mr. A. J. Marshall.—The architect, who for years has had full charge of the lighting system in buildings, has failed to develop the vital points necessary for the proper blending of utility and beauty. It seems, therefore, that the architect should not object to the illuminating engineer who proposes methods that will consider all of the points entering into a correctly designed lighting system. There are some illuminating engineers who are thoroughly qualified to undertake this class of work.

The architect feels that the illuminating engineer is treading on sacred ground when he attempts to follow his professional calling. The illuminating engineer feels that the architect knows

little or nothing about the fundamental principles of illuminating engineering, and, therefore, is not qualified to judge of his work. The Illuminating Engineering Society should endeavor to bind these interests closely together, having them all meet on common ground, feeling that each is working to the general good, and doing away with all possible friction. When the Society was started possibly it was necessary almost to antagonize certain interests in order to get them to enter into an argument, and thereby stimulate the general interest. However, the necessity to use such tactics no longer exists, as we are now one large family and well know each other's capabilities. My earnest plea is that we bury the hatchet and get together for the good of the cause.

Mr. W. H. Gardiner.—One of the elements of co-operation is for each man not to trespass on the other man's territory. I should be lothe indeed to see specialists in engineering abrogate to themselves matters of taste or matters of aesthetic judgment. Engineering deals with materialism or commercialism. Art is associated with the aesthetic sense, which is not measurable in any way by dollars, or purely material efficiency, so that, generally speaking, these two are entirely different.

Mr. E. L. Elliott.—It has been stated that Greek construction is the last word in architecture; that nothing better is possible. The fact is, however, that there is very little bona-fide Greek construction used in modern architecture. There are plenty of imitations. Fluted columns, Corinthian capitals and caryatides may be found on any number of sky-scrapers in New York; they are not Greek construction, but only veneer ornamentation covering up the steel beams underneath, which are the real structures. Modern construction has not yet been developed in architectural treatment of buildings. Where is there a building, for example, in which the steel frame construction is declared in its architectural treatment? Is such architectural treatment impossible, or is the lack of it simply due to the fact that no architectural genius has yet appeared with the courage and ability to accomplish the task?

No better example could be cited of the legitimate and thoroughly scientific use of decorative construction than the fluting on the columns of the Parthenon. The Parthenon stands on a

hill where it catches the full sunlight in the peculiarly transparent atmosphere of that region. A smooth column under such conditions would show harsh lights and shades, which would interfere with the perception of the cylindrical form of the column. The flutings break the heavy shadow up into lines very much as a draftsman would do in mechanical drawing, and thus, by bringing out the true form of the columns, show that the heavy portico is fully supported by pillars, thus satisfying the natural demand of the mind for a visible solution of the mechanical principles involved.

The chief aim of my paper was to bring out the fact that there is much common ground for the illuminating engineer and the architect; that neither should hold the other in distrust, but that they should heartily co-operate. Since the illuminating engineer has been accused, by implication at least, of being incompetent or incapable of artistic and aesthetic appreciation, it is not unnatural that the illuminating engineer should retort by pointing out some of the short-comings of the architect in this respect. I do not expect that all illuminating engineers will do uniformly good work; there will be many a botch job turned out by them from now until the end of time, just as there will be many botch jobs turned out by lawyers, doctors, and architects, until the human race is perfected—a time which I hardly expect to live to see.

Briefly, my contention is that in most cases of architecture which are of a commercial nature, the illuminating engineer should be competent to pass upon what is good and what is bad artistically, as well as scientifically; but that where the artistic treatment is paramount, there should be co-operation between the architect and the engineer.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. MAY, 1908. No. 5

A meeting of the Council was held on Friday, May 8. In the absence of President Bell, Mr. H. K. Mohr, as senior vice-president, presided.

The attention of the Council having been called to the fact that two members of the Society, who were elected on January 10th, 1908, and four members who were elected on February 14th, 1908, had not remitted for dues, and had failed to reply to notices of their delinquency, which were addressed to them by the General Secretary, it was ordered that the names of these men be removed from the membership roll.

The following ten men were elected members:

ATMORE, S., Foreman of Contract Dept., North Shore Electric Co., Evanston, Ill.

COMSTOCK, LOUIS K., Contracting Engineer, associated with L. K. Comstock & Co., New York.

DAVIES, HUBERT W., Superintendent, Pintsch Compressing Company, 303 South 30th Street, Philadelphia, Pa.

HIRSH, E. W., Electrical Contractor, 53 West 28th Street, New York.

HYDE, EDWARD B., Supt. of Office of New Amsterdam Gas Co., New York.

KELEHER, ARTHUR C. F., Salesman, Holophane Company, 227 Fulton Street, New York.

PERROT, EMILE G., Architect and Engineer, Asso. with Ballinger and Perrot, 1200 Chestnut Street, Philadelphia, Pa.

SCHROEDER, HENRY, Salesman, General Electric Co., Harrison, N. J.

SNYDER, FRANCIS, Jr., Secretary to Engineer of Construction, Consolidated Gas Company, New York.

TOWER, WILLIAM WARREN, Superintendent, Federal Sign System, New York.

An invitation was extended to the Council by the Board of Managers of the Philadelphia Section, to hold the 1908 Con-

vention of the Society at Philadelphia, during Founders' Week, October 5 to 12. This invitation was accepted.

The Council empowered Mr. Mohr, as Acting-President, to appoint a General Convention Committee. similar to the General Committee of last year's Convention, with a sub-committee of this General Committee for the Committee on Arrangements.

NEW YORK SECTION.

At a meeting of the Section held on May 14, Dr. Edward L. Nichols, of Cornell University, presented an illustrated paper entitled "Daylight and Artificial Light." This paper is printed in this issue, together with an account of the discussion following its reading. Secretary Millar announced that the Section will hold no further meetings until October.

CHICAGO SECTION.

A meeting of the Chicago Section was held in the Grand Pacific Hotel on May 14. The illumination of residences and small stores was the subject under discussion. The last meeting for the year will be held in June, at which time Dr. Henry Gradle will read a paper entitled "Illumination and the Eye."

PHILADELPHIA SECTION.

The May meeting of the Philadelphia Section was held at Odd Fellows Hall on Friday evening, May 15th, at 6:30 p. m., at which time an informal dinner was served. Mr. W. H. Gartley acted as toastmaster and presided. The following members made short addresses and apropos remarks: Vice-President Mohr, Chairman Bond and Messrs. Emile G. Perrot, James T. Maxwell. M. C. Whitaker, Walton Forstall, Joseph D. Israel, J. M. Rusby, Geo. Ross Green, J. B. Klumpp and John Meyer. This was the last meeting of the season. The Philadelphia Section will immediately take active steps towards assisting in preparing for the annual convention to be held in Philadelphia during Founders' Week on October 6th and 7th.

DAYLIGHT AND ARTIFICIAL LIGHT.[1]

By Edward L. Nichols.

It is a frequent claim of advocates of some new form of artificial illumination that it is like daylight or the nearest approach to daylight. Although such statements are often made only with the vaguest and flimsiest basis, they indicate a general belief in the superiority of daylight to our artificial means of lighting. It is the purpose of this paper to make some definite comparisons between daylight and artificial light which may possibly be of use to illuminating engineers.

SOME CHARACTERISTICS OF DAYLIGHT CONSIDERED AS ILLUMINATION.

Daylight is exclusively derived from the sun, which may be regarded as an incandescent source, having a temperature of about 6000° C., and which sends to us light of an essentially continuous spectrum. Sunlight is, however, greatly modified by atmospheric absorption. A varying proportion comes to us after selective reflection from minute particles in a turbid atmosphere, from cloud-masses and from the surface of the earth itself.

How profoundly sunlight is affected by transmission through our atmosphere may be seen from the averages for six months (Feb.-Aug., 1903) taken from the records of the Astrophysical Observatory of the Smithsonian Institution[2]. (See Table 1 and Fig. 1.)

TABLE I.

Average atmospheric transmission for zenith sun, Feb.-Aug., 1903.

Wave-length in cm.	Percentage Transmitted
$.80 \times 10^{-4}$	80.1
.70	75.6
.60	68.2
.50	62.4
.45	55.3
.40	47.5

[1] Read before the New York Section of the Illuminating Engineering Society on May 14, 1908.

[2] Langley, S. P., Astrophysical Journal, XIX, p. 313, 1904.

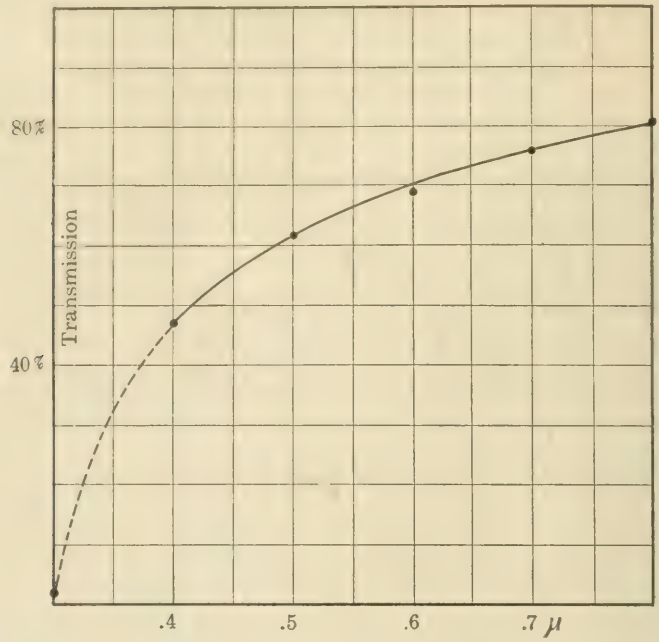


Fig. 1

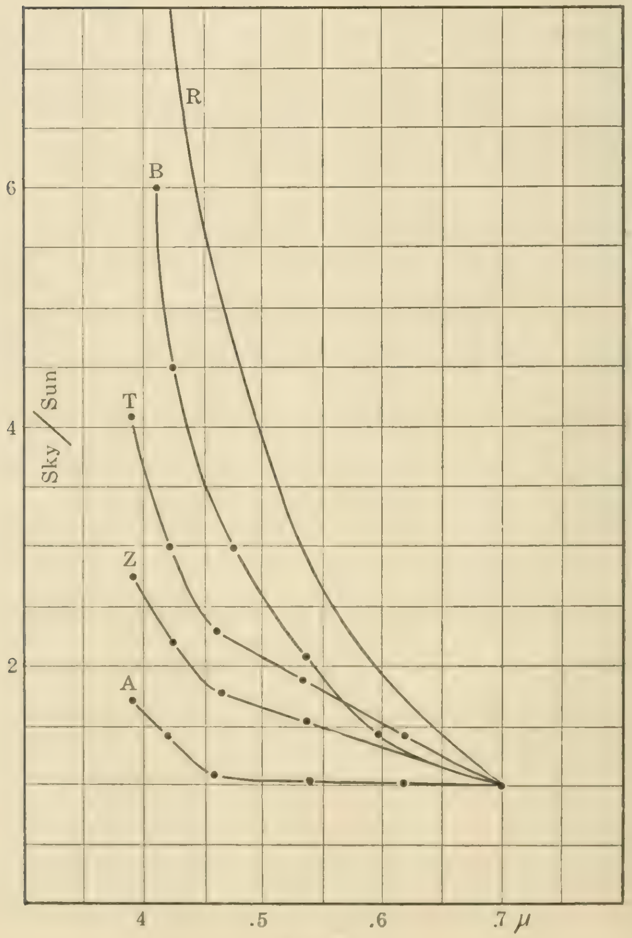


Fig. 2

It will be seen that the violet end of the sun's spectrum is reduced to less than one-half by passing through our atmosphere, while the red end loses less than 25 per cent. of its initial intensity. The ultra-violet is affected even more strongly[1]; so much so that the photographic spectrum of sunlight terminates at a wave-length of about $.30 \times 10^{-4}$ cm. Of the indirect components of daylight, that from the unclouded sky is relatively stronger in the blue and violet than sunlight by greatly varying amounts which depend on the state of the atmosphere.

The theoretical relation for the ideal sky, deduced by Lord Rayleigh from the properties of a turbid medium, the particles suspended in which are small compared with a wave-length of light, shows that the intensity of the diffused light of any given wave-length in terms of that of the incident sunlight of the same wave-length, varies inversely as the fourth power of the wave-length. The relative intensities of such a sky as compared with sunlight is given graphically in curve R, Fig. 2, the ratio of the sky to the sun being taken as unity at a wave-length of .70.

Actual skies, when compared with direct sunlight, rarely approach this ideal relation. They give curves very much nearer to sunlight. Thus B, Fig. 2, is plotted from the average of measurements made on five different days in March and April, by Bock[2] at Passau, Bavaria.

Summer skies have still less preponderance of blue even in the finest weather, as was shown by Crova[3] in a series of observations which extended over two years. Curves T, Z and A (Fig. 2), from measurements made by myself last summer at Trafoi (Tyrol), and at Zernez and Andermatt in Switzerland, are typical cases of summer skies.

At first sight one might expect that at elevated stations the curve would approach more nearly to the ideal, but that is not found, in general, to be the case. Indeed, some measurements made at the top of the Brienzer Rothhorn and at the Payerhütte on the Ortler, show less divergence from direct sunlight than at lower stations.

An unshaded surface receives sunlight and skylight in varying proportions. In bright weather, with unclouded sky, a

[1] Cornu: Journal de Physique 10, 1881.
[2] Bock: Wiedemann's Annalen 68, p. 674.
[3] Crova: Annales de Chimie et de Physique (6) vol. 20, p. 480; vol. 25, p. 534.

piece of black "needle paper," placed in a horizontal plane and illuminated by sun and sky, will sometimes be as bright as white paper shaded from the direct sunlight, so that the ratio of sunlit to shaded illumination is approximately 15 per cent. At great altitudes the ratio would doubtless be even greater. The other limit is unity for an obscured sun.

If we mean by daylight the illumination of an unshaded surface, this will then differ from sunlight but slightly in quality, since sunlight is the dominant factor. Daylight, defined as the light illuminating a shaded surface, will, however, always be bluer than sunlight, occasionally with the violet relatively eight or ten times as strong as the red, and ranging from this to light less than twice as blue as sunlight.

The human race, as I pointed out in a recent paper read before the National Academy of Sciences, having been developed in sunlight, has its organs of vision adapted, by long ages of exposure, to that particular stimulus. It is not to be regarded as a coincidence, then, but as the result of evolution rather, that the maximum of the luminosity curve for the normal eye (Fig. 3 L) is in the same region of the spectrum as the maximum of the energy curve of sunlight (Fig. 3 E).

Since primitive man, moreover, was not nocturnal in his habits, the range of sensitiveness of his eye is for daytime use, and he does not see as well by night as cats or owls. It is the extension of our activities to the hours of darkness, under the conditions of our new civilization, that has made artificial lighting necessary and brought into existence the important profession of the illuminating engineer. The acceptance of daylight as an ideal or standard by which to gauge our existing methods of artificial illumination, to determine its shortcomings and to ascertain, in the further development of the art, what to strive for and what to avoid, has a sound philosophical basis.

We may take as a general principle that *the normal stimulus of eye is diffused daylight, and that artificial stimuli which depart widely from it either as to intensity or quality are sure to be unsatisfactory and are likely to be injurious.*

The range of intensity of ordinary daylight, as between summer and winter, or between noontime in the open air on a fine day when the sky is filled with sunlit cloud masses and a dark overcast day indoors, is very considerable. We have data for the annual variation from L. Weber, taken at Kiel in Germany dur-

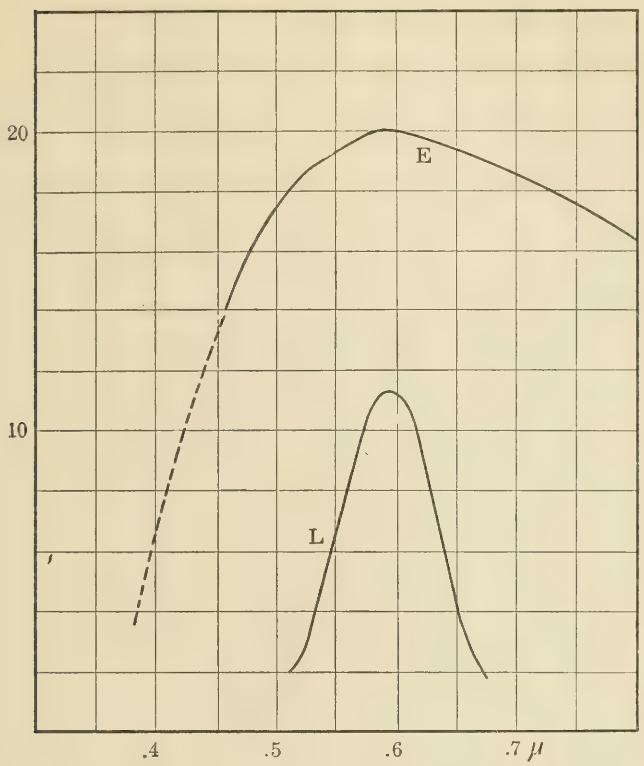


FIG. 3

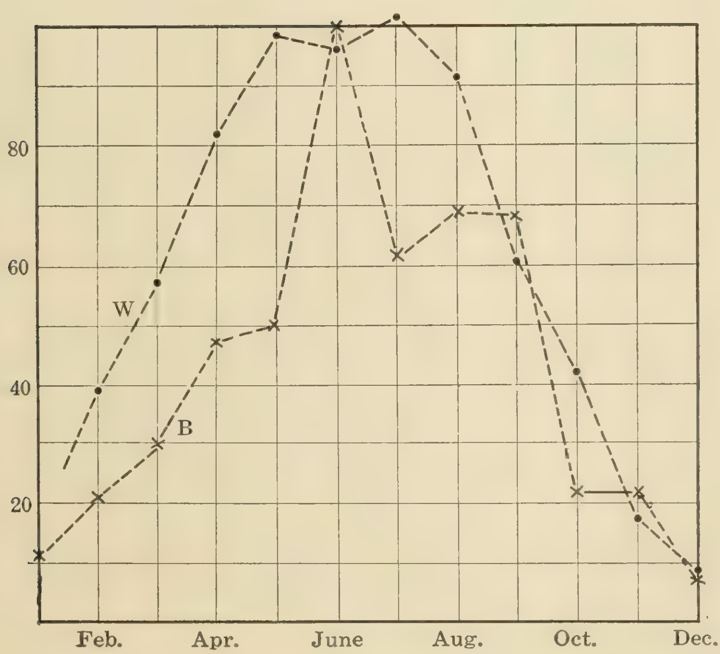


FIG. 4

ing 1890–92 with the instrument which has since become well known under the name of the Weber photometer[1]. His results, which are given graphically in Fig. 4 W, indicate about ten times as bright daylight in July as in December.

Basquin's curve[2], giving the results of similar measurements made in Chicago in 1898, is reproduced for comparison in the same figure (Fig. 4 B). It shows about the same total range, but is much less regular.

Professor Basquin, in the article just cited, has also published a curve giving the average range of brightness of daylight between 7.30 A.M. and 4.30 P.M. (see Fig. 5 B). It shows an almost symmetrical arrangement of values about the noontime maximum with a total range of about 3.5 : 1. Individual curves taken on fine days in summer indicate, as a rule, somewhat higher values in the afternoon and evening than at corresponding hours in the morning. Curve N (Fig. 5), which is from observations made at Sterzing (Tyrol) on July 18, 1907, is typical[3]. I began readings before sunrise and continued them at intervals until after sunset. The station is about 1000 meters above sea level in a mountainous region south of the Brenner Pass.

The shift in the curve in this instance was very marked. The illumination from the zenith was 1.44 times as great at 4 P.M. as at 8 A.M., and 2.5 times as great at 6 P.M. as at 6 A.M.

The excess of light in the later hours of the day is doubtless due to the gradual accumulation of condensed moisture in the atmosphere whereby the reflecting power—and consequently the brilliancy of the sky—is greatly increased. The mist is at first quite imperceptible to the eye, but tends in the afternoon to gather in white masses of sunlit cumulus. This was the case on the day during which the curve N was obtained.

The eye, although developed under daylight and adapted by long ages of exposure to it as the normal stimulus, admits of a certain range both as to intensity and quality; and a knowledge of this range is of the utmost importance to students of the science of illumination. That the intensity of full daylight—out of doors but protected from direct sunlight—lies near the upper limit, is

[1] Weber, L.: Resultate der Tageslichtmessungen in Kiel, 1890-92; Schriften des naturwissenschaftlichen Vereins Schleswig-Holsteins, Vol. X, p. 77, 1893.

[2] Basquin: Illuminating Engineer, Vol. 1, p. 829, 1906.

[3] No attempt has been made to reduce the ordinates of Curves B and N, Fig. 5, to a common value.

obvious. No one cares to read with the page exposed to direct sunlight. We may be quite free from fatigue in the brightest summer's days in the fields, but add the light from snow-covered ground or sometimes of water or white-washed walls and most eyes demand protection.

At heights of 3,000 meters or more above sea-level, exposure on sunlit snowfields involves injury from excess of ultra-violet. The eye will usually adjust itself within limits to mere brightness, so that sailors and fishermen do not have to resort to artificial protection, but the mountain guide who is on the snow daily throughout the season always wears dark glasses.

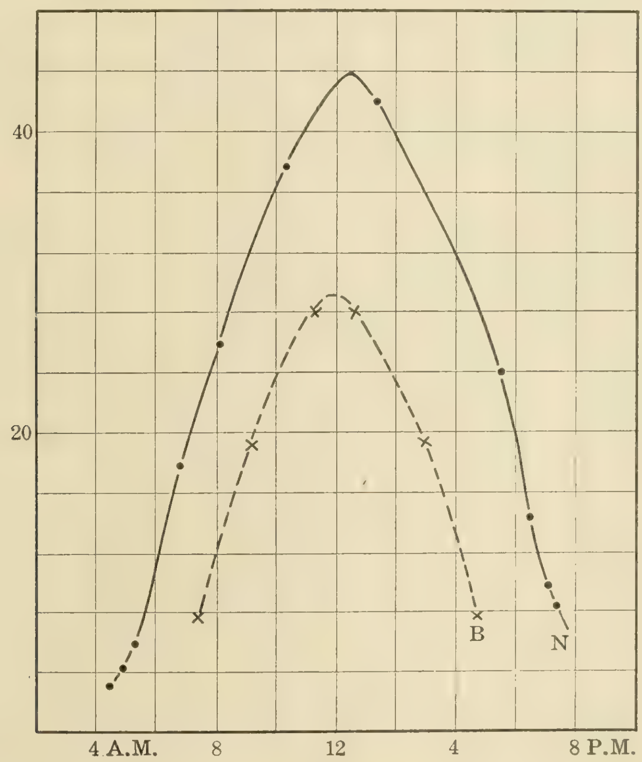


Fig. 5

This means that the absorption of the ultra-violet rays by the atmosphere is only just sufficient, at lower levels, to protect the eye, and that we are near the danger limit in this respect also. The point is confirmed and emphasized by the experience of those who have exposed their eyes to light sources rich in the ultra-violet, such as the mercury arc in a quartz tube or naked flaming arcs of certain types.

The average illumination from the entire sky in July, according to Weber's determination, reaches about 100,000 hefner-

meters. H. C. Vogel[1], who made similar measurements in 1897 at Charlottenburg, obtained for his summer maximum 78,000 hefner-meters. The results of Basquin, already cited, when expressed in this unit give about 33,000 hefner-meters for the month of June in Chicago, which is what one would expect in comparing sky illumination in a large and smoky city with that obtained in clearer atmospheres. It is an almost incredible step from these values, which represent approximately the upper limit of what the eye endures without undue fatigue, to the 12 hefner-meters which have been found to suffice for the easy reading of large print[2]. The latter intensity is nevertheless still further removed from the least illumination which will produce vision. From Langley's[3] determination of the minimum amount of energy which suffices to give the sensation of light to the eye it seems certain that the corresponding illumination is several million times dimmer than the minimum which is regarded as adequate for reading.

The intensity of illumination of the sky has not only its regular daily and annual variation which depend upon the position of the sun, but is subject to sudden fluctuations with the gathering and dissipation of cloud masses. I had an excellent opportunity to study this phenomenon on a showery day last summer. In the afternoon of July 15th, 1907, I was endeavoring to make observations on the color of the sky at the Tyrolese village of Sterzing, for which purpose I had set up my spectrophotometer in a quiet inn garden. At 5.30 P.M. the sky was quite clear and I began a series of readings. Within ten minutes, during which interval I made observations about two minutes apart, the clouds had been forming rapidly. At first, mere white sunlit threads of mist, then brilliant cloud masses filled the zenith, and finally a dark storm-cloud gathered which threatened immediate rain. Within the last minute the direct sunlight became entirely obscured.

The results are given in Fig. 6, in which the ordinates of the curve are intensities and abscissas are times at which readings were made. It will be seen that the illumination increased four-fold during the first eight minutes, reaching a maximum, and

[1] Vogel, H. C.: Wiedemann's Annalen, vol. 61, p. 408, 1897.

[2] Bell: The Art of Illumination, page 18.

[3] Langley: Energy and Vision: Memoirs of National Academy of Sciences, vol. V, 1888.

then suddenly dropped to its initial value. The maximum corresponded to the moment when the cloud masses within the field of vision had reached their greatest density previous to the obscuration of the sunlight. It is interesting to note that the illumination from the darkly overcast sky was the same as from the cloudless sky of ten minutes before. The identity of values is accidental, but by no means inconsistent with the generally observed fact. Basquin in his paper classifies the skies observed during the long series of observations made at Chicago into five groups, of which darkly overcast sky without sunlight and cloudless sky are of the lowest intensities. His averages show a brightness for the

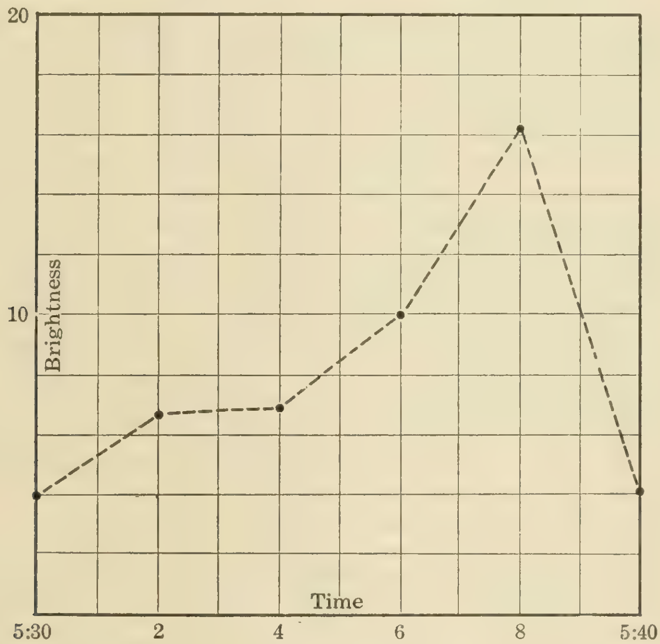


FIG. 6

unclouded sky of 1.5 times that of the overcast type. The identity of the values for these two skies in the curve in Fig. 6 means simply that the cloudless sky was clearer and consequently darker than the average of such skies in Chicago, which is to be expected, both on account of the locality—an Alpine valley—and because of the height above the sea (1,000 meters).

THE VARYING QUALITY OF DAYLIGHT.

The study of the composition of daylight is a matter of spectrophotometric comparison. In many of the determinations hitherto published, the reference standard has been direct sunlight; and for certain purposes, such as the investigation of the

modifications which sunlight undergoes in diffusion by the atmosphere and in reflection from cloud masses and from the surface of the earth it is the most suitable standard.

The study of sunlight itself shows however an exceedingly variable composition. Of direct comparisons between sunlight and artificial illuminants, wave length by wave length, but few have been recorded. Crova used for such purposes, as his comparison of standard, the Carcel lamp; H. C. Vogel, a petroleum flame;

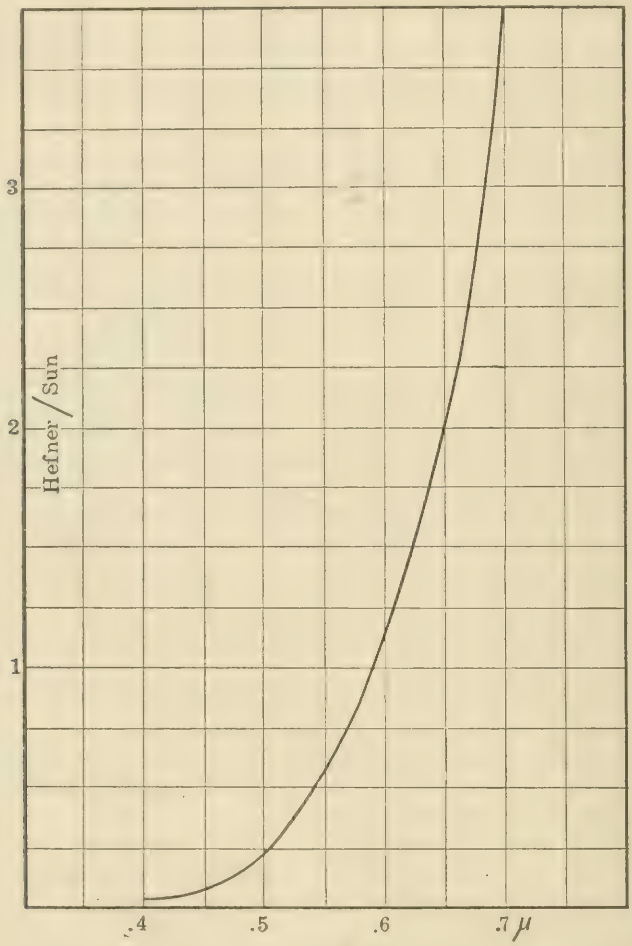


FIG. 7

W. H. Pickering, a gas flame; and Else Koettgen, the Hefner lamp. Miss Koettgen's measurements may be regarded as typical and they are referred to a standard concerning which our data are comparatively complete and definite. The curve given in Fig. 7 is from her data, but plotted in a modified form, so that ordinates represent the quantity $\frac{H}{S} \cdot \frac{S_{.59}}{H_{.59}}$ where H is the intensity of the spectrum of the Hefner flame for any region,

S the corresponding intensity of the spectrum of sunlight, and $\frac{H_{.59}}{S_{.59}}$ is the ratio of the two spectra for the region of the sodium lines. The curve indicates therefore the relative distribution of intensities in the spectrum of the Hefner flame as compared with sunlight where the two spectra are taken as of equal brightness at a wave length of .59. It will be seen from the curve that the strength of the violet of wave length, .40, in the spectrum of the Hefner flame is about $^1/_{70}$ of that of sunlight when the two are of equal strength in the extreme red.

An acetylene flame makes a much better comparison source, since it is relatively about five times as intense in the violet as the Hefner flame. Our knowledge of the quality of the light emitted is equally accurate. Had an acetylene flame been used in Miss Koettgen's work, the strength of the violet would have been about $^1/_{14}$ instead of $^1/_{70}$ that of sunlight.

During the summer of 1907 I made several comparisons of the red and violet respectively of sunlight with the corresponding wave-lengths in the spectrum of the acetylene flame. The results, which are given in the following table, show that the summer sunlight in various places in Switzerland was relatively weaker in the blue and violet than that measured by Miss Koettgen in Berlin, August, 1893.

TABLE II.

Values of the ratio of sunlight to acetylene flame in violet (wave length, .42 x 10^{-6} c.m.) when the two spectra are of equal brightness in the extreme red (.725 x 10^{-4} c.m.).

Station	Date	Sun/C_2H_2	Hour
Payerhut (on Ortler)	July 29, 1907	3.61	10:00 A.M.
St. Maria (Switzerland)	July 31, 1907	3.67	8:30 A.M.
Zernez (Switzerland)	Aug. 1, 1907	5.07	9:15 A.M.
Andermatt "	Aug. 9, 1907	10.20	10:30 A.M.
Brienz "	Aug. 13, 1907	3.57	9:15 A.M.
Brienzer Rothhorn (Switzerland)	Aug. 14, 1907	7.23	11:30 A.M.
Brienzer Rothhorn (Switzerland)	Aug. 14, 1907	4.95	3:30 P.M.
Brienz "	Aug. 15, 1907	4.12	9:15 A.M.
Brienz "	Aug. 19, 1907	9.90	9:45 A.M.
	Average -	5.81	

Crova,[1] who made many comparisons between sunlight and the carcel lamp on Mount Ventoux, France, found an average value which, computed for the same parts of the spectrum, equals 30, or, reduced to terms of the acetylene flame, about 6.

It would be interesting to have data on the variation in quality of direct sunlight from sunrise to sunset, but the results would doubtless be of greater importance to the meteorologist than to the illuminating engineer. So far as the problems of illumination are concerned we may rest with the statements already made of the very considerable range of sunlight as to quality, even when the sun is high, and pass to the consideration of the further selective modifications that occur in diffuse daylight. I shall illustrate these modifications by means of a few typical examples of skies taken chiefly from the results of an

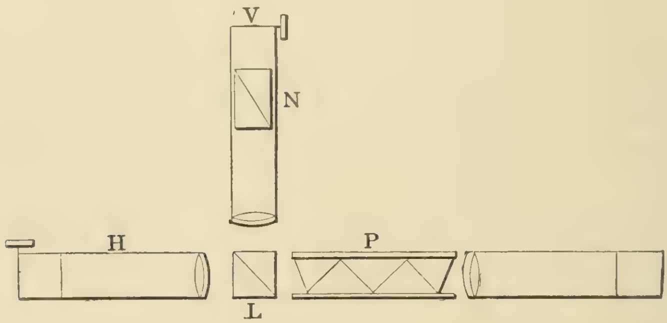


FIG. 8

extended series of spectrophometric observations which I made during a recent trip abroad. The instrument used was described at the February (1908) meeting of the American Physical Society. It is a simple form of Lummer-Brodhun spectrophotometer constructed with a view to lightness and portability, and modified to meet the conditions for traveling. It consists of a horizontal collimator (H), a vertical collimator (V), a Lummer-Brodhun cube (L), a set of direct vision prisms (P), and an observing telescope; (see Fig. 8). The vertical collimator contains a nicol (N) by means of which the component of the light from the sky polarized in the sun's vertical plane, or that at right angles to the same, could be studied. In front of the horizontal slit the comparison flame was mounted and all daylight was excluded from this collimator. The measurements were all made with the collimator tube through which the daylight en-

[1] Crova: Annales de Chimie et de Physique (6) XX p. 492.

tered the instrument pointed to the zenith. The slit was shaded from the direct rays of the sun and received light from a circular field of sky a few degrees in diameter. The comparison source was a small acetylene flame. In taking readings the width of the vertical slit was varied until the equality of the two spectra, in the region under observation, was obtained. The entire visible spectrum was thus explored step by step.

At dawn and after sunset in cloudless weather the light from the sky is sunlight diffusely reflected by the upper atmosphere and unmodified by selective reflection from clouds and earth. The curves obtained under such conditions are all of the same

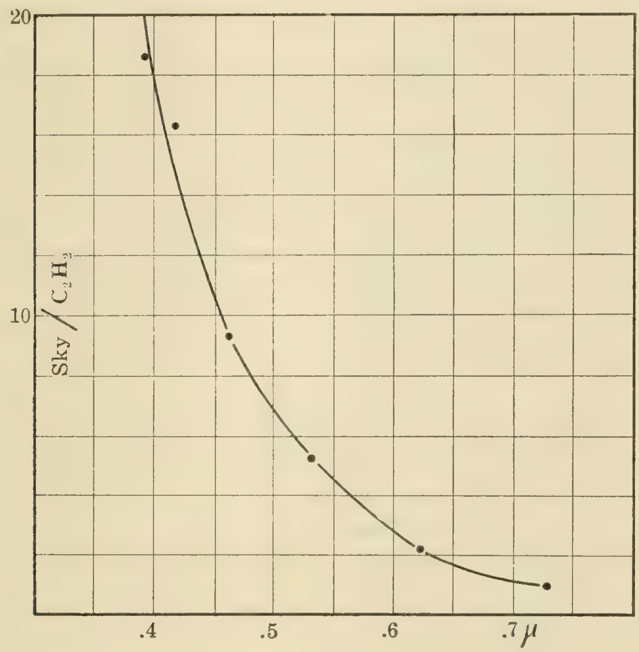


FIG. 9

type, showing only trifling variations in quality. The curve in Fig. 9 shows the mean of several observations taken before sunrise and after sunset in summer time. The ordinates of this curve, and of the subsequent curves excepting where otherwise specified, give the intensity of the spectrum of light from the sky in terms of that of the comparison flame, wave length by wave length. It will be seen that this typical dawn curve indicates a relative brightness of the violet from the sky about twenty times that of the spectrum of the acetylene flame.

After sunrise and when the landscape has become fully illuminated, say at 9 A.M. in summer, the light received from the zenith sky is sometimes increased about twenty fold as compared with

the brightness at dawn. On exceptional days when the air is unusually free from moisture the curve will be found to take the form shown in Fig. 10. It is necessarily plotted to a smaller scale on account of the increased size of the ordinates. The dawn curve plotted to this new scale is shown at the bottom of the figure. If we multiply the ordinates of the dawn curve by an amount sufficient to make its intensity in the red equal to

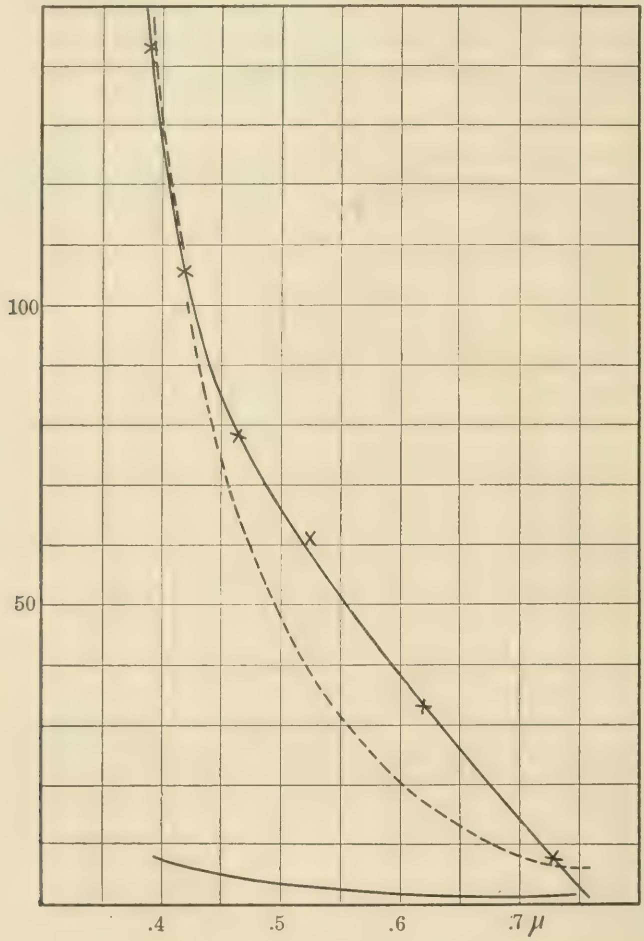


Fig. 10

that of the daylight curve we can more rapidly compare the two curves. It will be noted that while the relative intensities in red and violet are almost unchanged, the curves do not correspond in the intermediate portions of the spectrum. The discrepancy is greatest in the yellow region where the ordinate of the daylight curve is relatively twice as great as at dawn. That this selective difference is unquestionably due to the effect upon the color of the sky of light received from the brown or yellow soil of the earth and from foliage, I have already pointed out in

my recent paper before the American Physical Society. The effect upon the quality of skylight produced by the presence of sunlit fog, mist or cloud masses is quite different and is easily distinguished from that due to light reflected from the surface of the earth.

In ordinary fine weather, particularly in summer among the mountains, mist begins to gather as the sun gets high ; tending later in the day to the formation of cumulus. The effect shows itself in the form of the curves before the eye becomes definitely

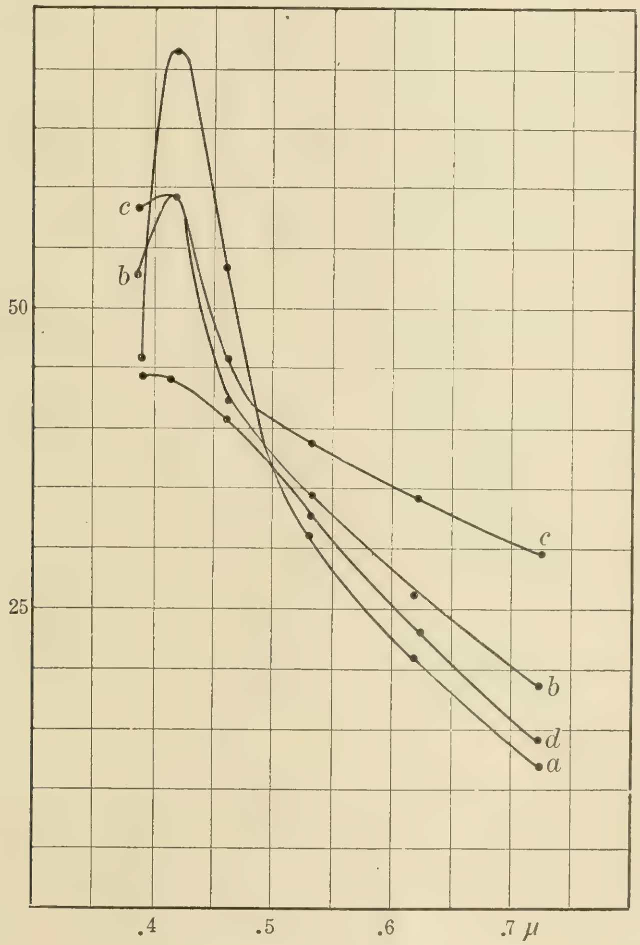


Fig. 11

aware of the change in the appearance of the sky. There is an increase in the brightness of the longer wave lengths ; not selectively with a maximum in the yellow, as in the case of the light from the earth, but extending to the extreme red. At the same time there is an extraordinary diminution in the extreme violet, as though the presence of the condensed moisture had produced an absorption band having its edge near the limit of visibility of the spectrum. Curve (*a*), Fig. 11, has been selected to illus-

trate this type of sky. The measurements were taken on the ice-field of the upper Rhone glacier, where the selective reflection from foliage and soil are nearly absent, although the gray rock of surrounding peaks doubtless contributes something to the light from the sky.

If the air be filled with sunlit fog through which the blue above is still dimly visible, the curve of intensities is further modified (see curve (*b*), Fig. 11). Measurements upon a mass of brilliantly white cumulus surrounded by blue sky gave the curve *c* (Fig. 11). When finally the sky becomes entirely overcast, excluding all directly reflected light, the remarkable selective features in the blue and violet are nearly or quite obliterated and the intensities throughout the spectrum are reduced. A typical case is illustrated in curve *d* (Fig. 11), which is from measurements made upon a uniformly cloudy but very bright sky at Vienna (10 A.M., June 7, 1907).

THE COMPARISON OF VARIOUS ARTIFICIAL LIGHT SOURCES WITH DAYLIGHT, AS TO QUALITY.

In attempting to compare the quality of artificial illumination in a definite and consistent manner with daylight it is necessary to have some standard to represent the latter. The difficulty in selecting this standard is evident when we consider the variations in the composition of the latter indicated in the examples given above.

Averages taken from sufficient data would afford such a standard, but would not be the same for winter and summer, nor for city and country, nor for stations at sea-level and in the mountains.

The measurements from which I have selected the foregoing examples of individual skies consist of about 150 sets of observations of which 115 were made during the hours of full daylight. They cover a period of about six months, Feb.-Aug. 1907, and include all the types of weather encountered during that period, although fine weather undoubtedly received more than its due share of attention, since there was no expectation of utilizing the results for obtaining such an average as is now being considered.

The sets were first averaged by groups, each wave length by itself; the observations in each locality constituting a group. A miscellaneous group was also formed consisting of various observations where only one or two sets were made in a place, as at Geneva (Switzerland), Salzburg (Austria), etc.

The results are given in the following table :

TABLE III.

Average intensities of the spectrum of daylight (in terms of that of an acetylene flame) in various localities.

I.

STATIONS NEAR SEA LEVEL OR AT MODERATE ALTITUDES.

Wave-length in cm.	At Sea (February) 3 sets	Algiers (February) 4 sets	Biskra (Algeria) (March) 20 sets
$.725 \times 10^{-4}$	1.98	2.84	4.26
.620	4.00	4.76	6.61
.530	9.62	8.94	10.89
.460	15.55	14.44	15.21
.420	20.28	18.17	20.23
.390	27.80	18.16	23.20

	Naples (March) 6 sets	Palermo (April) 7 sets	Taormina (Sicily) (April) 6 sets
$.725 \times 10^{-4}$	2.40	6.64	7.03
.620	5.20	10.44	14.01
.530	10.08	16.13	19.29
.460	16.72	22.28	29.94
.420	22.05	30.28	37.47
.390	25.20	33.70	48.53

	Bebek (Turkey) [1] (May) 4 sets	Vienna (June) 11 sets	Miscellaneous (Salzburg, Bozen, Geneva) 3 sets
$.725 \times 10^{-4}$	12.05	9.30	8.01
.620	17.50	12.37	15.61
.530	22.12	24.25	23.17
.460	28.75	33.95	41.73
.420	34.67	39.18	48.47
.390	38.20	43.50	49.23

[1] Measurements made during a week of unsettled weather with much mist.

II.

STATIONS AMONG THE TYROLESE AND SWISS MOUNTAINS.

Wave-length in cm.	Zell-am-See (Austria)[1] (July) 6 sets	Sterzing (Tyrol) (July) 15 sets	Trafoi (Tyrol) (July) 8 sets
.725 x 10^{-4}	13.04	9.33	7.17
.620	22.93	17.04	16.08
.530	29.32	25.70	26.95
.460	39.39	39.80	43.50
.420	47.88	52.40	54.80
.390	46.91	50.80	52.40
	Brienz (Aug.) 5 sets	Brienzer Rothorn (Aug.) 4 sets	Misc. (Swiss) (July-Aug.) 13 sets
.725 x 10^{-4}	8.20	5.84	8.52
.620	17.90	13.88	20.30
.530	28.10	23.50	33.85
.460	62.60	46.11	51.55
.420	72.39	55.47	64.35
.390	68.32	54.15	61.30

III.

GENERAL AVERAGES.

	.725	.620	.530	.460	.420	.390
Averages for I. (lower levels)	5.82	10.33	15.57	22.30	27.80	31.71
Averages for II. (Switzerland and Tyrol).	8.80	18.05	28.45	46.00	57.35	54.10
Averages for all Stations	7.13	13.70	21.22	32.75	41.02	41.60

A study of curves plotted from these group-averages shows a continued rise in all values with the advance of the season such as would be anticipated from the data for undispersed daylight obtained by Weber and by Basquin (already cited), as well as from the spectrophotometric measurements of Crova. It further appears that the measurements fall into two distinct classes, those made among the mountains of Switzerland and the Tyrol, and those from other stations. In Fig. 12 are plotted curves which repre-

[1] Measurements made during a week of stormy weather with occasional sunshine.

sent respectively the average of all the readings taken (*a*), the corresponding average for Switzerland and the high stations in the Tyrol (*b*), and the general average for all other observations (*c*). It will be noted that the feature, already discussed, of a maximum in the blue is well marked in the Swiss average, but has disappeared altogether from the average of the other curves.

Since the determination of the average *quality* of daylight is in question, rather than of intensity, the *various* curves may be reduced to a common basis by giving them all the same value in

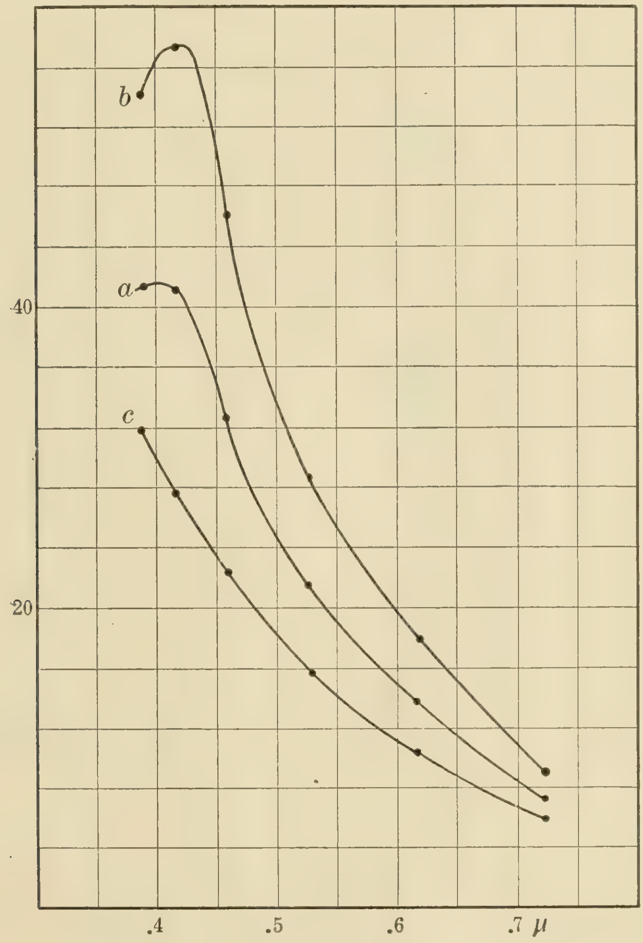


Fig. 12

the region of maximum luminosity at wave length .59 in the usual manner. Thus reduced, it appears that in spite of the wide range in the character of individual curves as affected by weather conditions, etc., the averages show a surprising degree of uniformity, at least in so far as the groups in question cover several days' work under varying weather conditions. The reduced values for all the group of the previous table are given in Table IV.

Table IV.

Values for the ratio daylight/C_2H_2 averaged by groups and reduced to the basis of equal brightness of both spectra at wave-length of .59 x 10^{-4} cm.

Wave-Lengths in 10^{-4} cm.

Stations	.725	.620	.590	.530	.460	.420	.390
At Sea	.367	.739	1.00	1.78	2.87	3.75	5.12
Algiers	.466	.764	1.00	1.47	2.37	2.97	2.96
Biskra	.538	.835	1.00	1.38	1.93	2.56	2.95
Naples	.444	.962	1.00	2.01	3.09	4.08	4.65
Palermo	.566	.873	1.00	1.24	1.85	2.52	2.81
Taormina	.423	.844	1.00	1.49	1.80	2.26	2.92
Bebek	.640	.928	1.00	1.17	1.52	1.84	2.03
Vienna	.562	.742	1.00	1.46	2.05	2.36	2.62
Zell	.528	.922	1.00	1.18	1.58	1.93	1.89
Sterzing	.468	.852	1.00	1.28	1.99	2.52	2.54
Trafoi	.358	.804	1.00	1.35	2.17	2.74	2.62
Brienz	.388	.848	1.00	1.33	2.96	3.43	3.23
Rothhorn	.334	.824	1.00	1.39	2.73	3.28	3.22
Misc. (Swiss)	.347	.850	1.00	1.42	2.17	2.70	2.57
Misc. (other)	.460	.900	1.00	1.33	2.39	2.77	2.83
Averages— Swiss, etc	.420	.859	1.00	1.35	2.19	2.73	2.58
Averages— Lower Stations	.490	.866	1.00	1.31	1.87	2.34	2.67
Averages— All Stations	.450	.865	1.00	1.34	2.07	2.59	2.63

Groups covering only a single day's work are affected both by the character of the surrounding landscape and by the accidental weather conditions and do not agree so well with the general average. It appears, however, that the average of all the curves, or the average of all but the Swiss readings, affords a sufficiently definite standard for daylight with which we may compare our artificial sources of illumination. Of how much influence upon the result is the inclusion or exclusion of the Swiss curves becomes apparent when we compare these three sets of averages reduced to a common basis, as shown in Table IV.

Having established our standard for daylight, all artificial light sources which have been compared with the acetylene or with the Hefner lamp may be expressed in terms of daylight, wave-length by wave-length. In accordance with the usual practice, the various ratios are reduced to a common basis by making both spectra of unit intensity in the yellow at wave-length .59.

Table V contains data for the ratio to daylight for the spectra of a variety of typical illuminants.

TABLE V.

Various sources of light compared with average daylight. (Ratio at a wave-length of $.59 \times 10^{-4}$ cm = 1.00.)

I Hefner Lamp			II Acetylene Lamp
Wave-lengths in cm.	Hefner/Sky "L"	Hefner/Sky "A"	C_2H_2/Sky
$.700 \times 10^{-4}$	2.670	2.790	1.847
.650	1.860	1.890	1.381
.590	1.000	1.000	1.000
.550	0.700	0.663	0.785
.500	.407	.380	.598
.460	.251	.223	.452
.420	.164	.145	.368
.390	.114	.114	.370

III Petroleum Flame		IV Gas Flame	V Glow Lamp (108V)
Wave-lengths in cm	Oil/Sky	Gas/Sky	(Carbon Filament) Carbon/Sky
$.700 \times 10^{-4}$	....	....	1.920
.690	2.650	2.270	....
.650	1.840	1.695	1.382
.590	1.000	1.000	1.000
.550	0.708	0.753	0.770
.510	.479	.560	....
.500	....	....	.581
.470	.303	.397	....
.460	....	....	.438
.430	.202	.306	....
.420	....	....	.353
.390	....	....	.351

VI METALLIZED FILAMENT

Wave-lengths in cm	(108-112 V at 110 V.) Carbon/CH_2	Carbon/Sky
.700x10^{-4}	1.090	2.020
.650	1.036	1.453
.590	1.000	1.000
.550	0.945	0.742
.500	.920	.550
.460	.790	.357
.420	.600	.221

VII TANTALUM FILAMENT

Wave-lengths in cm	At 109.5 V. Tantalum/C_2H_2	Tantalum/Sky
.700x10^{-4}	0.970	1.795
.650	1.001	1.382
.590	1.000	1.000
.550	0.940	0.740
.500	.825	.494
.460	.682	.309
.420	.540	.200

VIII NERNST FILAMENT

Wave-lengths in cm	At 0.8 Amps. Nernst/C_2H_2	Nernst/Sky
.700x10^{-4}	0.910	1.680
.650	.990	1.365
.590	1.000	1.000
.550	0.955	0.752
.500	.854	.510
.460	.747	.338
.420	.600	.221

IX TUNGSTEN FILAMENT

Wave-lengths in cm	at 110 V. Tungsten/C_2H_2	Tungsten/Sky
.700x10^{-4}	0.860	1.590
.650	.923	1.278
.590	1.000	1.000
.550	0.962	0.755
.500	.946	.566
.460	.935	.422
.420	.938	.347

X WELSBACH MANTLES
German (1894)

Wave-lengths in cm	New W/Sky	Old W/Sky
.670x10^{-4}	1.215	1.055
.650	1.495	1.315
.590	1.000	1.000
.550	0.877	0.972
.510	.723	.908
.470	.550	.765
.430	.428	.660

XI WELSBACH MANTLE
(American 1908)

Wave-lengths in cm	W/C_2H_2	New W/Sky
.700x10^{-4}	0.760	1.400
.650	.840	1.160
.590	1.000	1.000
.550	1.065	0.838
.500	1.030	.636
.460	1.060	.431
.420	0.80	.297

XII MAGNESIUM RIBBON BURNING IN AIR

Wave-lengths in cm	Mg/Sky
.700x10^{-4}	1.356
.650	1.148
.590	1.000
.550	1.116
.500	1.470
.460	1.675
.420	2.320

XIII OPEN ARC LAMP
10 AMPS., 50 V.

Wave-lengths in cm	½ inch carbons Arc/Sky
.700x10^{-4}	1.200
.650	1.140
.590	1.000
.550	0.911
.500	.692
.460	.576
.425	3.55
.390	.433

The artificial light sources under consideration may conveniently be grouped as follows :

Class I. *The older sources which owe their luminosity to incandescent carbon* (flames and electric glow lamps). As regards the quality of light emitted by this class, the Hefner lamp and the acetylene flame may be regarded as the extremes between which the other sources ordinarily employed take an intermediate place. Candles, oil and gas flames are very nearly identical with

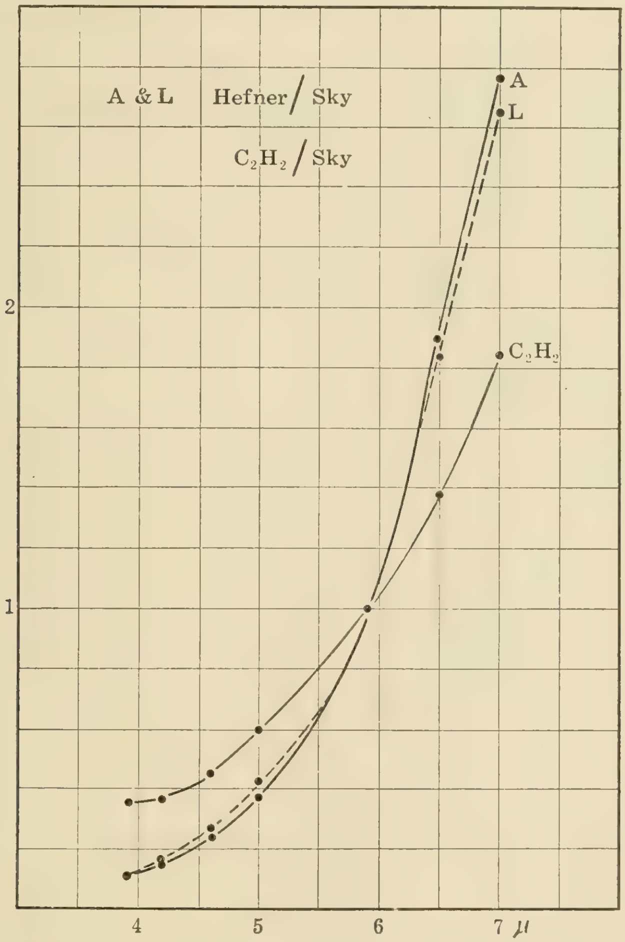


FIG. 13

the Hefner lamp, and the incandescent electric lamp of twenty years ago as commonly used on commercial circuits was scarcely to be distinguished in its color from these. Improvements in the conditions of combustion have gradually raised the temperature of such of these sources of light as have continued to be employed in modern illumination, bringing them nearer to the acetylene flame.

In the case of the Hefner lamp the resulting curves take the from shown in Fig. 13, in which L is the curve for Hefner/sky,

using the daylight values for lower stations (excluding Switzerland), while A is obtained by employing the general average for all skies. The slight difference between these curves is of no significance for our present purpose, and all further comparisons are therefore made with the general average as a basis. The curve marked C_2H_2 in Fig. 13 is for the acetylene flame.

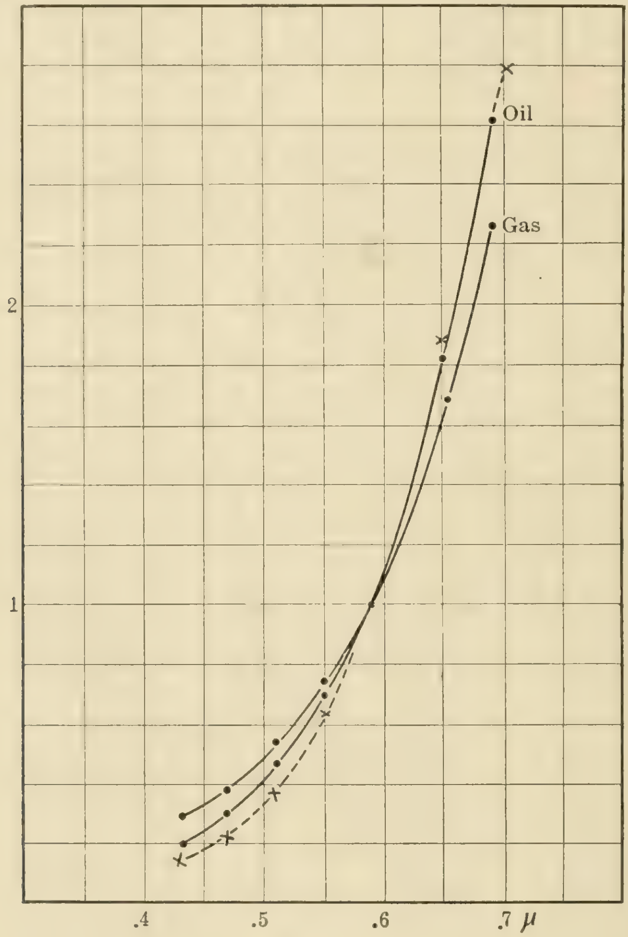


FIG. 14

The curves for an ordinary flat-flame petroleum lamp and for a gas flame (Sugg's standard burner) are shown in comparison with the Hefner flame, the curve for which is marked (X), in Fig. 14.

The data used were selected from Miss Koettgen's[1] extended spectrophotometric studies.

In order to obtain data which apply to every-day conditions it is necessary to take one's sources for comparison as they are to be found in actual service. To this end I have recently made

[1] Koettgen, l. c.

spectrophotometric measurements of the ordinary incandescent lamp with carbon filament, of the tantalum lamp, of foreign and domestic examples of the tungsten lamp, and of an American Nernst filament and have compared these with the acetylene standard flame at the voltages specified by the makers. One of the new "metallized" filament lamps maintained at the intermediate voltage indicated was likewise measured. The results of these measurements are all included in Table V.

The important characteristic of the newer high efficiency lamps with metal filaments consists in relative weakness in the red, a slightly increased intensity of the green and yellow, but no preponderance in the blue and violet as compared with acetylene.

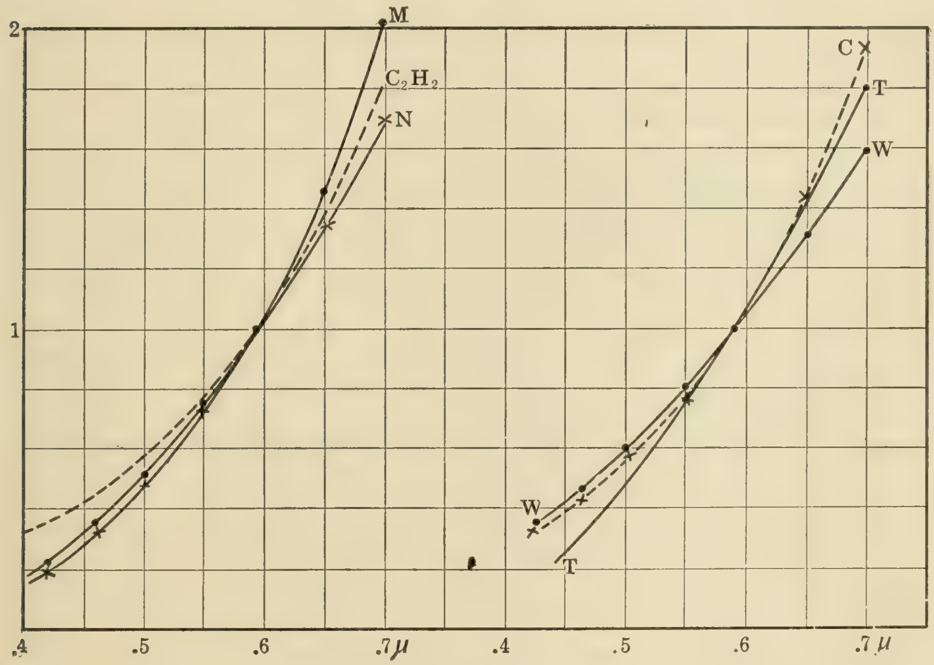


FIG. 15

lene. The tantalum and Nernst filaments, and the so-called "metallized" carbon filament, when of the same brightness in the yellow, are much weaker in the violet than the acetylene flame. The spectra of these newer incandescent lamps lie closer in quality or composition to acetylene than to the Hefner standard. Their differences as to color are by no means so marked as we are frequently led to suppose, and they all fall properly into Class I rather than into the groups to be considered later. To facilitate comparisons the various curves are given in Fig. 15.

The change in the distribution of intensities in the spectra of these sources, when compared with the radiation from carbon,

as in the acetylene flame or the carbon filament, consists, as mentioned above, in relatively greater amounts of yellow and green light. It is such as to make for increased efficiency, when measured in candle power per watt, since the flow of energy in the red end of the spectrum is great and the luminosity is small.

The simple form of all these curves, included in Class I, indicates that the type of radiation is very closely related to that which we receive from the sun, differing from the latter primarily on account of the lower temperatures. The practical identity, as to quality of flame sources, seems to indicate that the temperature attained by carbon ordinarily tends to a constant value which can be exceeded only by profoundly modifying the conditions of combustion. In the same way, considering the necessity of stability and long life, it may be said that the temperatures at which it is possible to maintain carbon, whether treated or untreated, and the various forms of metallic filaments, are not so very different in the various cases and that existing variations in efficiency are due in part at least to departure from the ordinary black body radiation in which the more luminous rays in the middle of the spectrum are relatively stronger than the red or the violet.

Class II. Another class of illuminants, *that in which the source of light consists of incandescent oxides*, shows selective radiation. To this class belong the lime light and zircon light, the Welsbach mantle, and the flame of burning magnesium. The Nernst glower likewise, by definition falls into this group, although when used under commercial conditions the quality of the light, as has been shown in Fig. 15, has little to distinguish it from the ordinary carbon sources. The extended series of comparisons with acetylene made by Hartman[1], which are in general agreement with the data from my own measurements given in the present paper, indicate this clearly. It is well known that it is possible to make glowers which furnish a quite different type of light, but apparently not, as yet, with sufficient life or stability.

The remarkable change in the quality of the lime light which occurs within a few minutes when a lime cylinder is exposed to the oxy-hydrogen flame was described some years ago.[2] Since this light has fallen into disuse, it will suffice to recall the fact

[1] Hartman, L. W.: Physical Review, Vol. XVII, p. 65.

[2] Nichols and Franklin: Am. Jour. of Science, Vol. XXXVIII, p. 100, 1888.

that the freshly-ignited lime considerably exceeds the acetylene flame in whiteness. (Lime light/C_2H_2 = 5.00 at .450 x 10^{-4}), whereas after ten minutes the ratio for the same wave-length is about 0.94. The zircon light, according to Miss Koettgen[1], is a trifle whiter than acetylene (zircon/C_2H_2 = 1.18 at .450)[2].

The Welsbach mantle shows, as is to be expected, very varied qualities, according to the composition used in its making, the conditions of combustion, and the age of the mantle.

Mantles studied in Germany several years ago by Miss Koettgen exhibited the remarkable weakness in the red, the

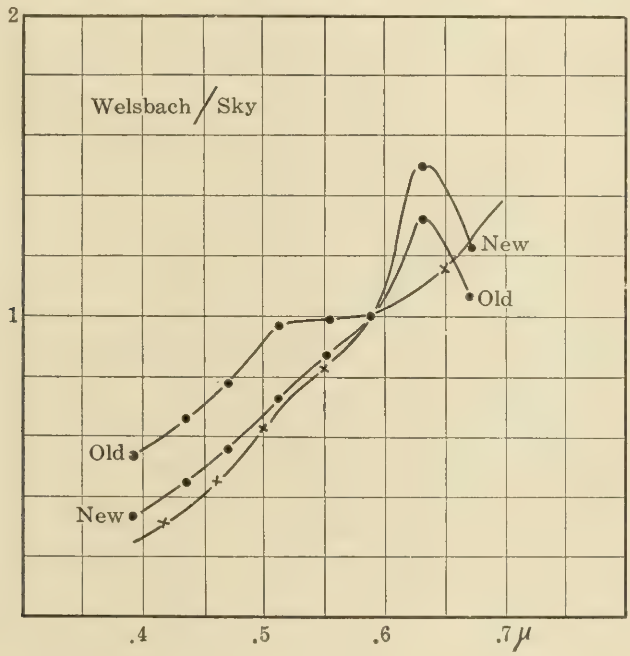


Fig. 16

pronounced selective maximum at .650 (yellow) depicted in Fig. 16. The changes in distribution of intensities throughout the spectrum with age is noteworthy, and this peculiarity was amply verified by the author of life-tests of such mantles with the spectrophotometer. A new mantle of American make, measured after one hour of incandescence (see curve x, Fig. 16), had a very different distribution and was less strikingly selective.

The flame of burning magnesium affords the most remarkable example, as yet subjected to measurement, of selective radiation. The curve for the comparison of this source with daylight is

[1] Koettgen, l. c.

[2] All these ratios, where not otherwise specified, are for equal brightness at .590.

computed from the determinations made by Rogers.[1] (See Fig. 17.)

On account of the importance of this source of light in photography, I give the data from which the Mg/daylight curve was calculated in the following table.

TABLE VI.

Distribution of intensities in the spectrum of the magnesium flame.

Wave-Length	Mg/Gas[2]	Mg/Sky
.700 x 10⁻ᵂ	.490	1.365
.650	.610	1.149
.590	1.00	1.000
.550	1.68	1.116
.500	3.87	1.470
.460	7.50	1.675
.420	16.00[3]	2.32

The light from magnesium may very probably be considered as due to two independent causes: incandescence at a high temperature, and intense luminescence of a type giving a band with a maximum somewhere in the ultra-violet. When the spectrum of the magnesium flame is equal to that of daylight in the yellow, it increases relatively towards the red by reason of its lower temperature of incandescence, and also towards the violet because of its luminescence. At .400 the Mg/sky ratio undoubtedly reaches a value of at least 2.5 with much higher ordinates for still shorter wave-lengths. To this extraordinary feature the actinic quality is due.

Class III. The remaining class of artificial light sources, *the spectra of which consist chiefly of a few or many bright lines*, are more difficult to deal with. Indeed, I know of no simple and direct way of comparing the various flaming arcs, the mercury arc or the vacuum-tube light quantitatively with daylight. Where the number of lines is very great and well distributed, one might apply the spectrophotometer as to a continuous spectrum and obtain an approximate result of some significance. In the mercury arc nearly all the light comes from three narrow

[1] Rogers, F. J.: Am. Jour. of Science, XLIII, p. 300.
[2] From measurements of F. J. Rogers.
[3] Estimated by extrapolation.

regions: the two yellow lines, which for this purpose may be taken together, the green line, and the brightest violet line, at wave-length .4358.

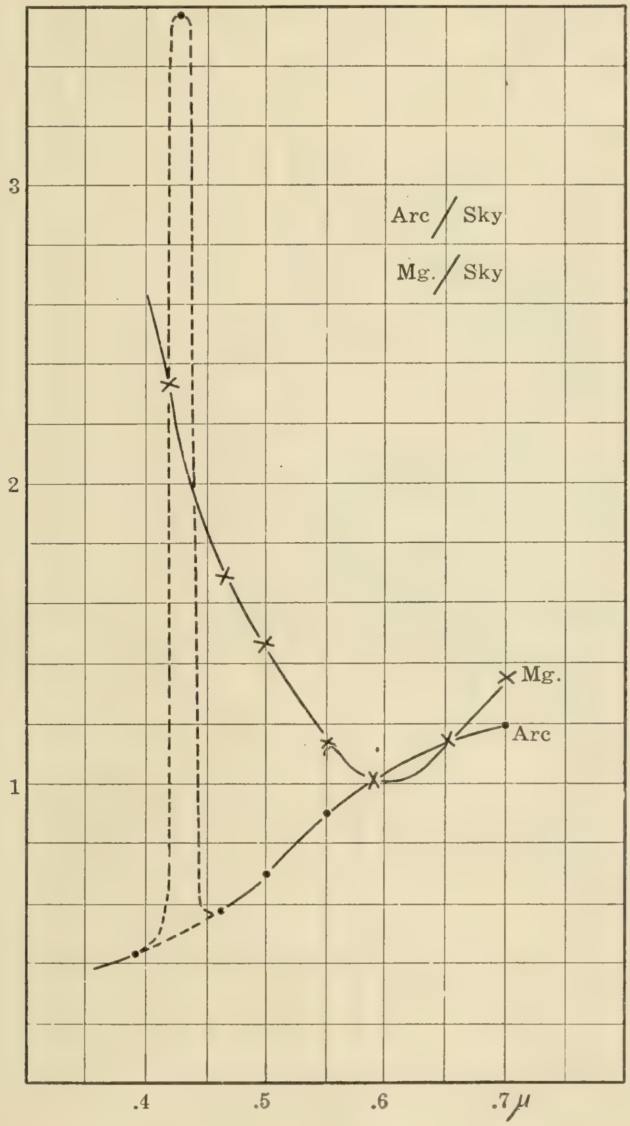


FIG. 17

If we compare the intensity of these lines with that of the corresponding regions of the spectrum of the acetylene flame we get the results given in Table VII.

TABLE VII.

Brightness of the lines in spectrum of the mercury arc, compared with corresponding regions in spectra of the acetylene

flame and of daylight (the ratio for the region of the yellow lines is in both cases taken as unity).

Yellow lines (.5790-.5769)		Green line (.5460)		Violet line (.4358)	
Hg/C_2H_2	Hg/Sky	Hg/C_2H_2	Hg/Sky	Hg/C_2H^2	Hg/Sky
1.000	1.000	3.75	3.00	16.81	7.85

These results are significant since, in a way, they enable us to describe this source of light.

We may take the brightness of the yellow lines as unity, since this region is approximately the same as that used in the reduction of previous data and thus compute the Hg/Sky ratios for the other lines as has been done in the table.

It will be seen that the mercury arc is nearly four times as bright as the magnesium flame at wave-length .4358 ; but this tells us but little by way of comparison, since for great distances on either side the ratio is zero.

If we attempt to define the quality of the light of the Hg arc by means of its effect in producing the three primary color sensations, using for the estimate the color curves of the normal eye as determined by Koenig[1] and Dieterici, we get :

Red 8.4 ; Green 30. ; Violet 50.70,

whereas ordinary daylight should produce these sensations in equal intensity [2].

The light of the ordinary carbon arc lamp partakes of the nature of the first and third of our three classes. It has groups of bright lines superimposed upon a continuous spectrum.

Where the carbons are unimpregnated, the only lines strong enough to appreciably affect the quality of the light are those of the band at wave-length .425. The curve, with respect to daylight from measurements upon a direct current open arc with half-inch carbons, supplied with 10 amperes at 50 volts, sufficiently describes the character of this source. (See Fig. 17 and Table VIII.)

[1] Koenig, A.: Wiedemann's Annalen 22, p. 572.

[2] Actual integration of the curves for the three colors, when the eye is stimulated by white light gives the following result, which is as near equality as could be expected: (Red ; 12.56. Green ; 12.46. Violet; 13.02)

TABLE VIII.

Distribution of intensities in the spectrum of a direct-current open arc lamp (10 amps. 50 volts).

Wave-length in cm	Arc/gas[1]	Arc/Sky
$.700 \times 10^{-4}$	0.45	1.20
.650	0.62	1.14
.590	1.00	1.00
.550	1.30	0.911
.500	1.70	0.692
.460	2.30	0.576
.425	....	3.550
.420	3.10	....
.390	3.80	0.433

The intensity of the violet band fluctuates greatly, but the value given is a fair average for the ordinary self-regulating commercial lamp. Its relative brightness is somewhat less than twice that of the corresponding region in the spectrum of the magnesium flame and somewhat less than half that of the violet line in the mercury arc.

SUMMARY.

Daylight, as to intensity and quality, is to be regarded as the normal stimulus of the human eye. At its brightest it represents very nearly the upper limit of intensity at which the eye can work without fatigue and injury.

The mean annual range in intensity is about 10:1 between midsummer and midwinter.

Illumination (in the shade) is less for unclouded skies and overcast skies than for any intermediate type of sky.

The modified sunlight which constitutes daylight, varies greatly with atmospheric conditions, but is always bluer than sunlight.

Average values for the relation of daylight to the light of an acetylene flame, taken from 115 sets of observations for various parts of the spectrum, are used as a standard with which to compare artificial light.

[1] Nichols and Franklin, l.c.

Comparisons are given for numerous artificial sources of illumination belonging to the following three classes :

Class I. Incandescent carbon and metals.

Class II. Incandescent oxides.

Class III. Incandescent vapors (mercury arcs, etc.)

Of the sources studied, no one approaches identity with daylight as to composition although the relation of Class I. to the same is a simple one easily expressed in graphic form. Class II shows more or less marked selective radiation. The bright line spectra of Class III cannot be simply compared to daylight.

PHYSICAL LABORATORY OF CORNELL UNIVERSITY.

April 18, 1908.

DISCUSSION OF PROF. NICHOLS' PAPER BY THE NEW YORK SECTION.

Prof. Hallock—The science of illumination owes a very lasting and decided debt of gratitude to Prof. Nichols for settling several questions to which he has referred; among others, that most forms of illumination are of the same type as daylight, and that hereafter we shall be able to answer the frequent inquiry as to which one of the artificial sources of illumination is most nearly like daylight, by, I presume, replying that none of them is near enough like daylight to be worth while making a comparison.

I was very much interested in the fact, although patent enough to those familiar with distribution of energy in the solar spectrum, which I had never noticed before, that the maximum of the visibility curve coincided with the maximum of energy. Of course that is a goal for illuminating engineers to strive toward, and perhaps they can get such a source of artificial illumination operated at a temperature of 5,000 or 6,000 degrees. However, it may be borne in mind that there is a side entrance to that goal that is not quite so difficult to penetrate. According to the researches, for example, of the late Prof. Langley, a fire-fly, which evidently has been developed under the same illuminating conditions as those which we have, has probably not only developed his seeing organisms to satisfy the illumina-

tion, but he has been able to provide a source of artificial illumination which has its maximum in the place where, strange to say, the maximum visibility of the human eye occurs. I think, perhaps, we have a right to infer that not only have we developed higher sensibility to see most efficiently by means of the illumination which has its maximum in the yellow, but even the animals also have developed a maximum for visibility effect in the same place; the fire-fly has a purpose for his illumination, and probably the true purposes are very well served by the sunlight and by his own lantern which give him a maximum of visibility in the same place.

Dr. A. H. Elliott.—I can only echo the words of Prof. Hallock in admiring the amount of work that Prof. Nichols has put upon this problem during a vacation. It is astounding, the amount of work he has done in so short a time, and it is pretty hard to digest it in the time we have at our disposal this evening.

The thing that strikes me in conjunction with this is the relation it has outside of illumination, that is the application of the idea to color photography. The Lumere brothers have been working along this same line, and succeeded in producing color photographs by a system of colored starch grains in photographic plates, which seems to be further advanced by some of the work Prof. Nichols has done.

Prof. Nichols has stated the proportions of violet green and red light that may be used to produce white light. It is noteworthy also that Dr. Steinmetz has suggested that three colors be superposed to obtain a standard of light composition. An interesting outcome of these investigations and suggestions would be the adoption of such a light unit.

Mr. J. W. Howell.—I was somewhat surprised, and a good deal pleased, to find that Prof. Nichols' work brings the different artificial illuminants so close together in their characteristics when compared with daylight. He gives the keynote of the situation when he says that all of the lamp filaments operate at temperatures between 1,600 and slightly over 2,000. The temperatures vary quite perceptibly among themselves, but when compared with the temperature of the sun, which is about 6,000 degrees, they are really close together. This is the secret of their having so nearly like characteristics. Prof. Nichols' paper

will be a reference paper on this subject for a long time to come. And I wish it had been on record before the presentation of the papers on the effect of the different illuminants on the human eye. If this paper had been on record the statements made concerning the varying effects of the illuminants would have been modified somewhat; conclusions were made too hastily, and with too little data. This paper causes us to consider them with less alarm than we were apt to consider them at the time they were presented.

Mr. John W. Lieb, Jr.—The paper before us is an unusual one to be presented before American societies, involving, as it does, thorough scientific research, and it ought therefore to be all the more welcome. This is the kind of research and careful experimentation which has been too much monopolized by foreign scientific investigators. I think, therefore, that the work of Prof. Nichols should meet with our hearty appreciation, as signalizing the appearance of the kind of paper which will exalt the work of American scientists.

Mr. J. E. Woodwell—The paper is valuable not only for the review which it presents of the great research work which has been done mainly abroad, but also for the large proportion of original matter which it contains. It marks, one might say, a new epoch in the work of the Society, and in the field of illuminating engineering, in directing our specific attention more to the quality of the light than to the intensity. We have been inclined perhaps to attach too much weight in the past to the intensity of illumination, and in developing our light sources have come to place almost foremost the question of efficiency.

We have recently succeeded in securing the most remarkable advances within the last decade in the new forms of tungsten and other metallic-filament incandescent lamps, etc., and can now turn our attention more specifically to the question of color and quality of illumination. This paper presents some valuable data which can be well studied to this end by the illuminating engineer with a view to its application in our future work.

Mr. A. H. Kellogg.—The statement was made that the light from all artificial lamps is so widely different from daylight that to all intents and purposes the lighting effects are the same.

One frequently hears that one or another lamp gives a more satisfactory result, a light nearer to daylight, than others. The tungsten lamp is supposed to give a very white light, and it seems to me, as far as my limited experience goes, that the true color effects, in a department store, for example, can be better detected by the tungsten lamp than by any other. I would ask whether all such claims are wrong, or whether it is a fact that one form of artificial light is better than another for the display of goods.

Mr. P. S. Millar.—Our artificial lighting has been, broadly speaking, by incandescence. There is every reason to believe that the human eye is satisfied by an illumination intensity of something like 3 foot-candles from the artificial illuminants. On the other hand, with daylight, we are accustomed to work with an illumination of five or ten times that intensity. I would like to ask Dr. Nichols what part, in his opinion, the difference in color value between daylight on the one hand, and the light from artificial illuminants, grouped on the other hand, plays in the varying apparent demand of the human eye for such widely different intensities of illumination.

Dr. Nichols.—It does not follow, because two lamps produce light of compositions that differ very little from each other as compared with daylight, that therefore there is no appreciable difference in the effects produced by them in illuminating certain colors which are affected by small differences.

A large portion of the difference in the demand of the eye for intensity of illumination is probably attributable to the diffuseness of daylight as compared with the light from the ordinary means of illumination. I believe it is an established fact that if in a room with concealed lamps a person is asked when the light is correct for reading purposes he will demand considerably greater illumination than, perhaps twice as much as, he would if incandescent lamps are put where they can be seen. With a candle held in the hand illuminating the page and lighting a sheet held in the other hand, for some reason or other we seem to be content with less light.

The light of the fire-fly has been mentioned by Prof. Hallock. This light has one common characteristic with daylight, namely, its maximum lies in the same region of the spectrum

as the luminosity curve of the human eye. In order to obtain the highest possible lighting efficiency the lamps should give rays in this region. It is not likely that temperatures higher than in the carbon arc will ever be employed. However, in the direction of luminosity there is a field as yet almost untouched. High efficiency is obtainable by selective radiation, but certain difficulties are encountered. Although luminescent bodies exhibit a continuous spectrum, and the distribution of energy is of the same sort as obtained in temperature radiation, yet it is in the form of one broad band instead of extending throughout the visible spectrum as in the case of the light of the fire-fly. We do not know yet of any phosphorescent spectrum in which the band is broad enough to fulfill the conditions of ideal illuminations. There are cases of phosphorescence at higher temperatures which give all the intensity needed; but it is too high. It may be that a combination of such substances, and making overlapping bands, we might fill up a sufficient region of the spectrum to imitate the white light fairly well. However, I have measured with the spectro-photometer a great many phosphorescent bodies, and found all to have the same characteristic band; the band is always rather narrow.

RELATION OF DIRECTION OF LIGHT TO HUMAN CONSTRUCTION.

By Jno. J. Sorber.

The last great occurrence in the formation of the earth was the fall of the last great ring or envelope. This was the watery envelope. Before it fell, while the waters were suspended as vapor in a thick layer about the earth, no direct sunlight reached the surface of the earth. The rays of the sun striking this vapor became diffused so much that there was little or no shadow and in passing through this vapor the actinic or chemical rays were extracted so that decay was very slow to start. Beneath this the temperature was very even and the supply of moisture liberal. For these reasons vegetation grew more rapidly, attaining gigantic proportions, but required much longer to reach maturity then at the present time. Thus also did it affect humanity. Compared with the present as manhood age, men were then but children and they lived much longer.

Fermentation, one of the first signs of decay, was probably unknown. Without fermentation intoxicants and intoxication did not exist. With direct sunlight came also speedier development, a shorter and more active life, quicker decay, fermentation and intoxicants. We have the story of the queer antics of Noah with his grape juice to support this. He knew nothing of fermentation and with the slow time-consuming methods to which he was accustomed, his grape juice became wine and he got drunk.

The foregoing, touching on some of the unusual effects of light which do not appear in every day problems such as we now have to deal with, briefly surveys the conditions up to the time of the change. This change in the method of lighting the earth from diffused to direct sunlight was very great. Since that time we have had pronounced shadows and they have become necessary to us in forming correct ideas of shape, distance, and color. The present arrangement for lighting the earth is simple, but important—a large source at a very great distance. Naturally, if our seeing mechanism were not suited to this lighting previous to the flood, it gradually adjusted itself to the new conditions and to-

day this method is the correct one. On the contrary, had the Creator ignored harmony by hanging many small suns close to the surface of the earth on celestial fixtures, our eyes would no doubt have become adjusted to this latter method, and we could properly carry this scheme into our homes, business houses, and gathering places.

Certain it is that physically we are so constructed and our ideas so firmly fixed, from ages of living under present conditions, that were the sun obliterated and many small suns substituted, low hanging, on fixtures extending down from the sky, the beauty of the sky would be sadly marred and seeing made more difficult. All of us would probably register a strenuous protest to have the sun again put into service.

Another phase is worthy of consideration. The direction of light probably had much to do with enabling man to graduate from the four-footed class and to walk on two legs in an upright position, and also with keeping beasts on four legs. Should the sun through all these ages have been just above the horizon, humanity would wear its face close to the ground and be four-footed. If the sun during its daily lighting period had been just above the horizon, either in the East or West, and had humanity been built as at present, our movements would be mainly in North and South directions. That our construction would not be as it is seems reasonable, because man's active time is during that part of the day when he receives light from above. He ceases to be active when the light is received horizontally. Quadrupeds are most active when the light is being received horizontally and they rest during the time it is received vertically. It follows then that should the times of activity be reversed, the forms would be reversed—man would be a quadruped and quadrupeds would be bipeds, with a change at least in some degree in relative superiority. Even the fish, active and normally horizontal when the sun is low, would assume a vertical position with conditions reversed. The Esquimaux, who has for centuries received light almost horizontally, is already affected by it. Today he is very short and rather wide; the light at least was a great factor affecting his shape directly and indirectly. At the equator similar signs may be found. For instance, the Pygmies of Africa. Here the heat prevents activity when the sun is high. In both cases civilization has either been slow or retrograde. For still another sign,

observe the common impulse when facing a setting sun to pull the hat down in front, incline the face forward and seek the shadow. This points to a reason why quadrupeds never abandoned the use of fore legs as did man. Being most active morning and evening when no bodily appurtence shades the eye, because it would obstruct vision, the quadruped has continued to keep his eyes near the ground for protection from the direct rays of the sun. It may be argued that man's activity during the sun's "high period" did not cause him to rise to a vertical position, but that his vertical position determined the time of his activity. It matters little which view we may hold. It is none the less evident that the direction permitted him to raise his eyes relatively higher than the beast and that were the sun always in a "setting" position, he also would have sought protection in the same way and this would have thrown the arm into service as a bodily support to maintain equilibrium by keeping the center of gravity of the body within the base of support.

That artificial light has had no bearing on form is evident since it is comparatively modern. The architect, engineer and user, knowing that human construction necessitates light from above and realizing the importance of shadow, should cooperate in applying to interiors the principle found outside. Difficult though this may be, the lack of efficiency can no longer be urged as a bar to its adoption. The cooperation of these three parties seems to have been without sufficient regard to the demands imposed by human construction. It must be borne in mind that during the evolution of man he was an "open air" animal. He lived, grew, and was shaped to suit the open. This includes the eye and its setting. Daylight diffusion as we find it today inside played no part in developing the eye, for man's habitation was a hole in the side of a hill and he went there only for protection. Getting back to nature should be beneficial to the eye as well as to the lungs. Outside proportions where the distance from the source of light is 11,000 times the diameter of the surface lighted obviously cannot be obtained inside, because man is limited in his ability to build interiors, especially in regard to height. He must then modify his light sources, both in size and number. This modification in the past has frequently been extended far beyond the point where judgment tells us to stop, and far beyond the point now necessary.

The paucity of devices on the market was largely responsible for this, but human beings, like sheep, are inclined blindly to follow the beaten path and for no other reason continue the use, or because, of many small light sources, hung low instead of a small number of large sources at greater height. An endeavor to obtain star-light effects might justify a great number of small sources, but they too should be high.

Before man had decided to move about on two legs he would probably have been fairly well suited with low light sources, and interiors lighted in this manner would no doubt have been popular 100,000 years ago. Conversely such interiors should have for inhabitants men and women of that by-gone age. To the proselyte to that form of lighting this suggestion might be of assistance. For a given room, use only one source in a corner, at eye height or lower, as powerful as practicable and provide obstructions in lieu of rocks and bushes, behind which to crouch for protection. This might be preferable to a great number of low hung units from which there is no protection and should produce a purer type of savagery.

Shadows may be by some considered rather unimportant, because we seem to see about as well in diffused sunlight as in direct sunlight. For our requirements this may be true, but were our requirements greater it probably would not; at any rate even on days when there is no direct sunlight there is considerable shadow, but there is less sharp contrast between light and shadow and because the blending is gradual, we do not notice it. With perfect diffusion, if such a condition existed, surfaces would appear much too flat. A friend a few days ago cited the lighting in a photograhper's studio to show that with perfect diffusion and no shadow we would see very well. The photographer, if told that he had perfect diffusion, would stand aghast. His endeavor is to smooth out the harsh contrast which the camera has a trick of exaggerating. Ruskin says: "Photography either exaggerates shadow or loses detail in the lights."

Were it not that shadows are always present the work of the architect would not seem so good—exteriors particularly. In interiors, with the numerous light sources and correspondingly complex shadow effects, the problem seems more difficult, but the adoption of the principle found outside will no doubt simplify it.

The following from Ruskin concerning shadows is interesting and instructive:

"They are in fact commonly far more conspicuous than the thing which casts them, for being as large as the casting object, and altogether made up of a blackness deeper than the darkest part of the casting object, their large, broad, unbroken spaces tell strongly on the eye, especially as all form is rendered partially, often totally, invisible within them and as they are suddenly terminated by the sharpest lines which nature ever shows." . . . . "Shadows are in reality when the sun is shining the most conspicuous things." . . . . "Next to the highest lights, all form is understood and explained chiefly by their agency; the roughness of the bark of a tree for instance is not seen in the light nor in the shadow—it is only seen between the two." . . . . "It is the constant habit of nature to use both her highest lights and deepest shadows in exceedingly small quantity." On *Principles*—"Nature observes, even when she is most working for effect—when she is playing with thunder-clouds and sunbeams, and throwing one thing out and obscuring another with the most marked artistic feeling and intention; even then she never forgets her great rule to give precisely the same quantity of deepest shadow which she does of highest light and no more." Again—"For form can only be seen by shadow of some kind or another." In reference to the paintings of Turner, he says: "Powerful and captivating as his color is, it is the least important of all his excellences, because it is the least important of nature."

The importance of shadow in assisting us to see things is emphasized by the case in which nature minimizes its effect to prevent us from seeing—it is that of the wild fowl—the upper and dark colored portion in the light and the lower and light colored portion in the shadow makes it almost invisible. Reverse the position and it at once becomes easy to see. With perfect diffusion there would be no difference.

Shadow depends on direction. We know that the eye should be shaded. Malpractice in lighting might be followed by irritated eyes to irritated tempers, and so on, indirectly resulting in deaths, destroying happiness and retarding progress, for very little is some times required to change the course of a whole life, and the very lives necessary to propagate the race might be lost

or so changed as to lose their necessary force. A single case will illustrate this more clearly. A workman has a boy, who, under proper conditions, would be a great inventor, but the father, due to misplaced light, becomes irritable, vents his irritation on wife, family neighbors and employers, loses his chances to better himself, earns less, moves to unhealthy quarters, and the boy goes to work too young if he doesn't die, receives a poor education and gets no further than his father. For all he has done, the world stands still, simply because of misplaced light. A healthy imagination might take direction, quality, steadiness, intensity or a combination and follow good or evil effects far enough to indicate the great importance. I believe the elements of proper lighting practice are so important that they should be taught in the public schools. No one can estimate the value of a better knowledge and practice in health, happiness and progress.

As this paper is intended to show the relation of direction to form, no attempt will be made to determine sizes of lamps, fix heights, or establish center distances between them. This relation points to the necessity for confining direction within certain limits, but these limits may not always be the same. For example, the limits may be greater in places where headgear is worn than where custom impels us to remove it. In accomplishing this result probably a better artificial sky can be obtained. This also is a problem not nearly solved. Another point of interest is that the eye has no natural protection from light rays delivered from below, and again, artificial protection cannot be interposed because it would interfere with vision. This condition indicates that the use of light colored floors is injurious and should be discontinued. Snow-blindness supports this view. We might go further and make the application to table covers were it not for the fear of inciting rebellion by running counter to "good taste." As table covers are a matter of decoration, they can be left for later attention, not, however, without a word of commendation for those who have abandoned them in favor of the mahogany, innocent though they may be of any consideration for the eye. Walls effect the direction of light considerably and they may be said to be to interiors what the mixture of trees, hills and sky is to the exterior.

It was fortunate, indeed, for the human race that when the Creator said "Let there be light" the light was from above, be-

cause when man stood upright his arm was no longer used as a support, and the freedom permitted the perfection of the hand, one of the chief means by which he attained his superiority. The hands used as feet could help but little in lifting him from bestiality, but hands as hands are proving of the utmost importance in his journey to Utopia.

DISCUSSION OF MR. SORBER'S PAPER BY THE CHICAGO SECTION.

Mr W. R. Bonham.—The point made by the author relative to the public schools is very good. Our public school teachers should be required to have at least an elementary knowledge of illumination so that they can teach the children the proper position of the body with reference to the light source. Children frequently place their heads below their shoulders, thereby retarding the circulation of blood to their eyes. They should be taught to realize that the head should be held erect when reading. I believe we are harming our eyes more today by using too much light rather than not enough. Years ago, when the tallow candle and kerosene lamp were in use, people did not experience trouble with their eyes as we do at present. Mr. Sorber seems to go back into the far distant past looking for the cause of things and I have wondered in view of the fact that his paper is rather extraordinary what caused him to write such a paper. We have the effect and I should like to know the cause.

Mr. Geo. C. Keech.—As stated by Mr. Sorber better illuminating results may be obtained from large lighting units placed high than from small units placed low. I recall one case in particular where the covering of a printer's composing case, his copy and typestick were equally illuminated by using large lighting units,—a result which could not have been obtained with small units. It has been found impossible in Post Office work with small low-hung lighting units to illuminate the letters being distributed equally as brilliantly as the spaces into which the letters were being thrown. In each of these cases uniformity of illumination is desirable in order to prevent injury to the eyes.

Mr. R. W. Hiett.—An oculist has cautioned me against us-

ing white paper for drafting, especially when working at night or for any considerable length of time during the day. I have found from experience that blue typewritten matter does not tire the eyes so much as black. Moreover, cream-colored paper causes considerably less trouble to the eyes than white glazed paper. One oculist told me that a considerable portion of his business was caused by poorly lighted drafting rooms, etc.

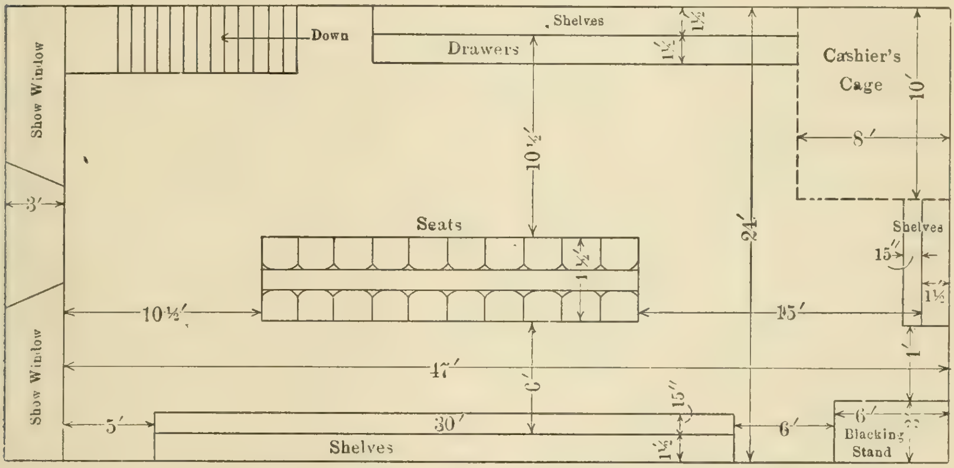
Chairman J. R. Cravath.—There is no doubt that the glazed papers that have come into use with half-tone engravings have been somewhat injurious to our eyes. With such paper, reading is a strain on the eyes unless the light strikes the paper at the proper angle.

Mr. Sorber—In reply to the question as to the reason for presenting the paper of the evening, I may state that the principal one was an endeavor to establish a basis for correct practice in illuminating engineering from which to work, instead of working backwards, as we seem to have been doing in the past.

In regard to the use of artificial light, I believe it will not prove injurious if properly utilized. Experience shows that we do not need as much sleep as there are night hours. If the human race breaks down from over-time work, it will probably stop such work and go to bed earlier.

THE LIGHTING OF A SMALL SHOE STORE.—A PROBLEM IN ILLUMINATING ENGINEERING.*

The accompanying illustration shows a plan of a small shoe store for which a proper lighting equipment is to be selected. The distance from the ceiling to the floor is 11 feet; that from the bottom of the window to the ceiling is 9 feet. Goods to



ARRANGEMENT OF STORE TO BE ILLUMINATED.

be displayed in the window will be arranged along only the floor of the window; that is 9 feet below the ceiling. The walls are colored buff, and the woodwork has a natural finish.

THE LIGHTING OF A SHOE STORE WITH INCANDESCENT ELECTRIC LAMPS.

By H. V. ALLEN.

The following recommendations are offered as to the lighting with incandescent electric lamps:

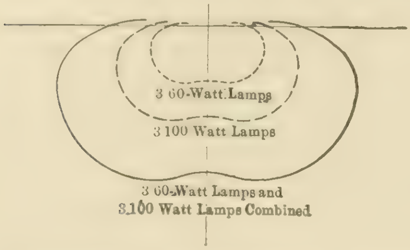
GENERAL ILLUMINATION.

Four "Economy" diffusers, each equipped with three 60-watt and 3 100-watt clear-bulb tungsten lamps should be hung at a height of ten feet from the floor, outlets being arranged in the middle line of the store equally spaced 12 ft. 9 in. apart.

* Presented at a meeting of the New England Section held on April 14.

LOCAL ILLUMINATION.

One 60-watt tip-frosted tungsten lamp with prismatic bowl reflector frosted on the inside, should be used at the cashier's desk. Each window should be equipped with two 100-watt tip-frosted tungsten lamps with prismatic reflectors frosted on the inside. The front of the glass should be opaqued from the top to a distance sufficient to prevent the lamps coming in direct line of sight.



Apparent Distribution of Light at a Distance of Ten Feet with "Economy" Diffuser.

The above recommendations are made in order to obtain the following results:

1. The store has the appearance of added height by installing the lighting units near the ceiling.

2. There is as small a number of light sources as is consistent with uniform illumination.

3. Intrinsic brilliancy of the unit is not sufficiently great to fatigue the eye and thereby decrease the real illuminating efficiency.

4. The circuits are so arranged that three steps of illumination may be obtained without any sacrifice of uniformity.

5. The fixture is so designed that the temperature of the lamps is kept within safe limits, and the decrease in life due to frosting is avoided.

The intermediate value of illumination using 300 watts per fixture or 1.06 watts per sq. ft. is recommended for working conditions. The 180-watt combination is intended for use as an auxilliary to daylight. The 480-watt combination should be employed only on special occasions when conditions will justify the use of high intensity of illumination.

THE LIGHTING OF A SHOE STORE WITH NERNST LAMPS.

By A. T. Holbrook.

The lighting of a shoe store is a science in itself. It is necessary not only that the store should present a well-lighted appearance, but that the value and volume of light should be in places where it is most needed, that is, at the utmost extremities reached

by the light rays. All shoes are sold on the customer's foot. The presentation of the shoe as to fit, shape, color and appearance are studied by the customer from an elevation of from three to four feet from the floor, and he must be presented with the article under the most favorable conditions of lighting in order to effect a sale readily. A poor lighting arrangement, or one which shades or shadows the shoe so that it does not stand out clearly, usually results disastrously to the shoe dealer, while under more favorable lighting conditions the sale would be readily effected.

The maximum intensity of illumination and the clearest and best light in a shoe store, should be approximately one foot from the floor. An ideally lighted shoe store has a good value of illumination on the shelves and side walls, for the salesman is oftentimes in a hurry and he should be able to distinguish mark. size and color from the floor, regardless of whether the boxes are within reach or on the topmost row. He should be saved from mistakes which consume valuable time and irritate an impatient customer. In order to be able to distinguish the marks, there must be more than a "reading" value of light even to the highest point reached by the boxes.

A shoe salesman operates under a peculiar disposition of mind while he is making a sale, and is carrying in his mind's eye what he considers to be an ideal fit and shape that would be most pleasing to the customer. In order that he may carry this vision clearly and unhampered, ample illumination must be supplied on all sides.

A lighting installation which would have all of the beforementioned characteristics would consist of six two-glower Nernst lamps, fitted with bell-shaped prismatic shades and clear heater cases, the lamps being hung directly from the ceiling on suitable supports, bringing the top of the lamps as near to the ceiling as convenient. The glowers are thus brought down 12 in. from the ceiling and 10 ft. from the floor.

In figuring the illumination, the angles have been taken from the point where the light from the glowers meets a 10 in. perpendicular line reaching from the floor toward the ceiling. The lamps are spaced 6 ft. apart across the width of the room, making 6 ft. from wall to lamp and 12 ft. from lamp to lamp, and 7 ft. apart down the length of the room, 7 ft. from the front wall to the lamp and 14 ft. from lamp to lamp, making two rows of three lamps each. The area to be illuminatetd by the six lamps does

not include 5 ft. in depth by 24 ft. in width in the rear, the area occupied by the cashier's desk and the boot black stand and also shelving, etc.; these are specially lighted by two 110-watt single-glower Nernst lamps. One of these lamps is on a drop cord, directly over the cashier's cage, 2 ft. 6 in. from the ceiling, the glower reaching a point 8 ft. from the floor. The other lamp is hung midway between the side wall and the outside of the cashier's cage, 3 ft. from the end wall on a lamp cord 2 ft. 6 in. from the ceiling.

The electric consumption per square foot of floor area is 1.24 watts. The windows are assumed to be of the false ceiling pattern, boxed in at the 3 ft. line from the glass in the usual sweat-box style. The rear line of the window has a doorway to allow for entrance and egress for dressing and cleaning. The ceiling is assumed to be 8 ft. from the floor of the window, and without rise and pitch; the windows thus being 3 ft. wide and approximately 10 ft. long are to be lighted by three 110-watt Nernst lamps fitted with clear balls and special-designed mirror-lined window reflectors, the reflector to be of the shovel type, placed directly against the glass facing the window and projecting the light directly into the window and against the goods.

It will be seen that this arrangement will eliminate all shadows in front or between the outside and the goods, and that the goods will present a shapely, defined and clear cut appearance, attractive to the eye and in accordance with the manufacturer's design. The shades themselves, projecting 12 in. below the false ceiling are hidden either by a band painted across the window, or by a reflector with the false ceiling, or by a strip about 16 in. in width placed entirely across the window.

The windows will thus use a maximum of 10 watts per sq. foot of floor space and receive an illumination of 9.2 foot-candles at all points. The store proper is very evenly lighted. A cross-section diagram across the width would show 2.5 foot-candles directly underneath the lamps, 1.89 foot-candles midway between the two lamps, 1.12 foot-candles at the corners, 1.09 foot-candles three feet from the floor, .876 foot-candles at a point 6 ft. from the floor and .78 foot-candles 9 ft. from the floor. The total electrical power is 1,936 watts—1,276 for the store and 660 for the windows. The value for the watts per sq. ft. is 1.25 over the store area.

THE LIGHTING OF A SHOE STORE WITH INCANDESCENT GAS LAMPS.

By H. M. Daggett, Jr.

Leaving out the spectacular or advertising use of lamps, store illumination divides itself into two parts, outdoor illumination and indoor illumination. There are a good many stores using lamps over the sidewalk. Some use them for wholly or partially lighting the inside windows by the aid of special angle reflectors and one-half sand-blasted vertical globes. I do not consider this plan good, because a brilliant exterior illumination requires more light inside than would otherwise be necessary. The greater the contrast between the light inside and outside, the better lighted will the window appear and the better the goods on display will be exhibited. Therefore, I do not advocate the use of outside lighting where proper inside window lighting can be accomplished.

There are no particular specifications about the windows except that they are three feet wide and approximately eight feet long. I should recommend making the windows dust tight and placing a false ceiling or deck 18 inches below the main store ceiling. This arrangement leaves the height of deck 7½ feet above the window floor. The deck should be made with a rectangular opening in its center, 12 inches wide by the length of the window, into which is placed a ground glass of the same size.

Directly over the glass in each window are to be placed seven "Reflex" inverted gas lamps, approximately 12 inches

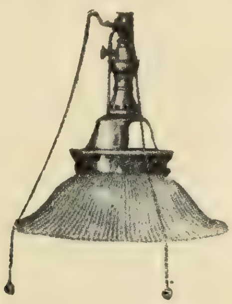


Fig. 1. Gas Lamp and Prismatic Reflector.

between centers, equipped with No. 6333 Holophane concentrating reflectors. (Fig. 1.) The mean spherical candlepower of this unit is taken as 54. Seven lamps would, therefore, give 378

total spherical candlepower for each window of approximately 24 square feet. Allowing 30 per cent. for absorption of the ground glass leaves 264, or an average of 12 mean spherical candlepower per square foot of floor space. Every closed window should be ventilated to prevent freezing, whether or not the lamps are inside, and it is recommended to leave an open trough of generous size in the front floor of the window, covered on top

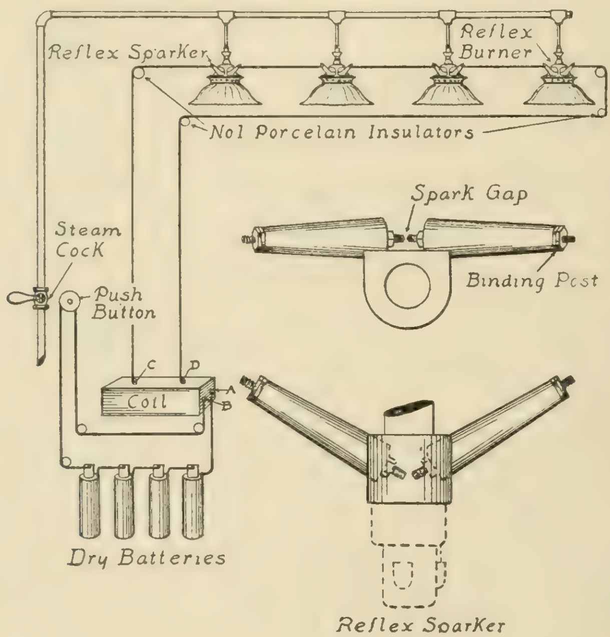


FIG. 2. ELECTRIC SPARK SYSTEM.

by the usual copper gutter but left open under the inside edge. This opening should preferably be connected with the outside air, as cellar atmosphere is often damp and would of itself cause frosting of the glass. There should be an outlet for the air in some inconspicuous part of the ceiling. A good circulation of outside air will prevent any window from frosting.

If is often desired to partially light the windows as dusk comes on, and for this reason it is recommended to double-pipe each window so that part, or all, of the lamps may be used. By placing a main cock behind each separate line cock, only one operation is necessary to light the entire window. The cocks for both windows should be placed at one convenient point.

The high-tension electric spark is the system I should use for the lighting. (Fig. 2.) All of the 14 lamp spark-gaps may be connected in series and the push of a button will light any line or all the lamps according to the cock turned. By turning No.

1 and pushing the button, all the lamps are instantly lighted. If only one line is desired to be used, turn off, for example, Nos. 3 and 5, when by turning key No. 1 the lamps on line 4 are lighted. All of the cocks may be placed in a cabinet for that purpose and the pipes concealed, the batteries, induction coil and push button being in another, thus having all of the mechanism out of sight. By connecting cock No. 1 with a simple

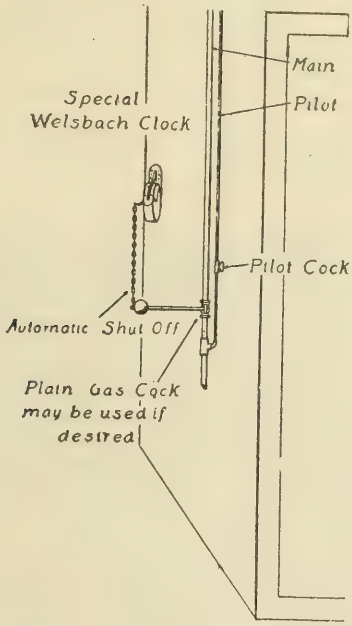


FIG. 3. GAS-PIPING SYSTEM.

time-shut-off clock (Fig. 3) the windows lamps may be left on, and automatically shut off at any time desired.

These details are gone into on this part of the description because it is sometimes not known that such conveniences may be had with systems of gas lighting.

The candlepower curve of the "Reflex" lamp with No. 6333 Holophane reflector is shown in Fig. 4: Its maximum cp. in the vertical direction is 314-317 at 10 degrees from vertical, 250 at 20 degrees, and 116 at 30 degrees. Covering an angle of 40 degrees directly under the lamp there are concentrated more than 250 cp. For this reason, it is an admirable reflector for the lighting of windows where the units may be, and are desired to be, placed close together. By the insertion of a one-sided ground glass (smooth side up) the light is materially softened and broken up, as well as reduced. I do not know the exact redistribution of light from this arrangement, but have made a curve

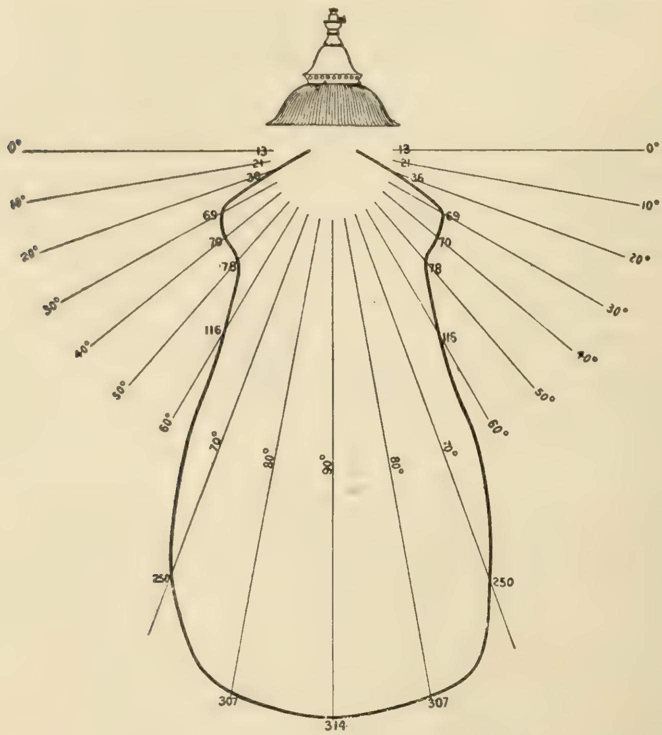


FIG. 4. LIGHT DISTRIBUTION FROM GAS LAMP WITH PRISMATIC REFLECTOR.

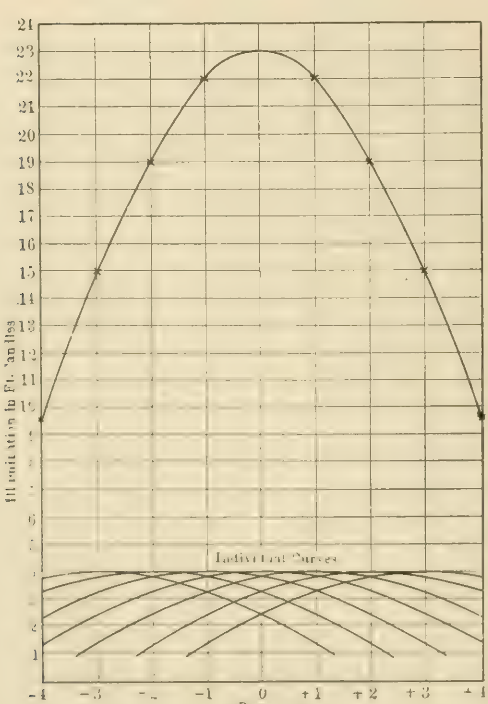


FIG. 5. ILLUMINATION WITH SEVEN GAS LAMPS AND PRISMATIC SHADES.

showing the foot-candles on the floor of the window (Fig. 5) after estimating 30 per cent. absorption for the ground glass. The curve would be very much flatter than it appears, due to the effect of the ground glass. The foot-candle value is high—average about 16—but not excessive for showing black goods. Practically all the light is thrown on the goods; the small amount distributed upwards is amply sufficient for lighting an 18-inch sign-transparency in the upper part of the window. This, beside being a good advertisement, keeps the lamps in the window out of sight.

The intrinsic brilliancy of the ground glass is very low and offers absolutely no attraction to the window gazer (unless inter-

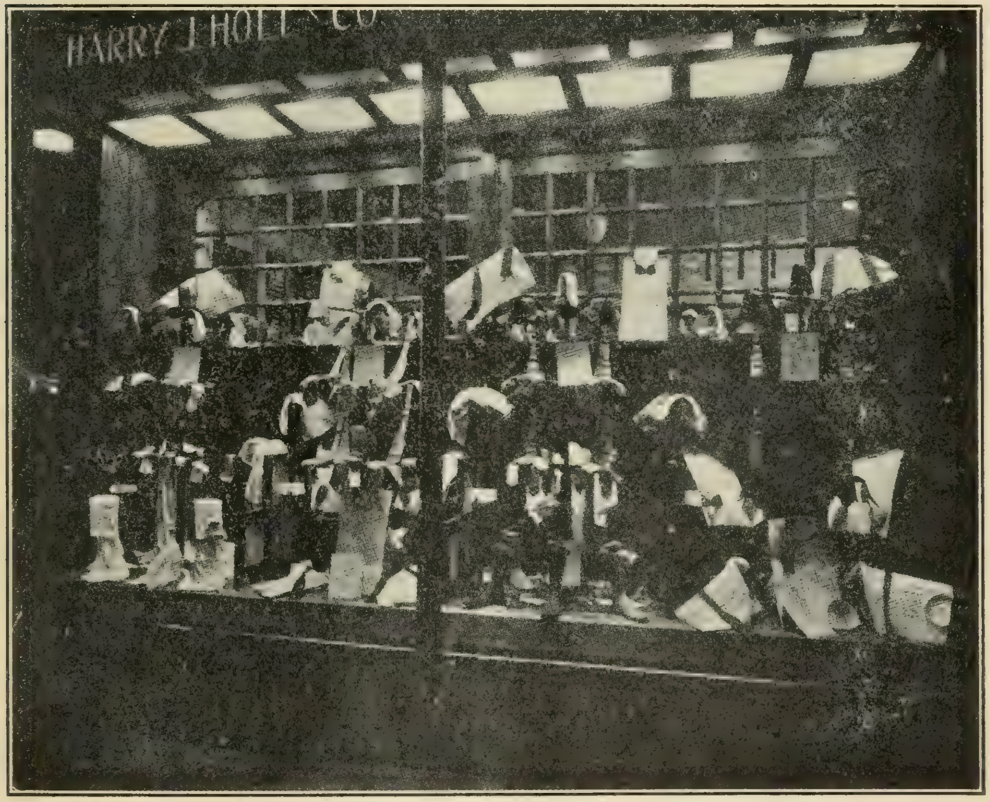


Fig. 6. Well-Lighted Store Window.

ested in lighting) and the goods are shown off in their true qualities. A window with this illumination is plainly visible from the sidewalk several stores away. One cannot help but be attracted by it, and cannot but look at the goods which stand out so prominently, and which give the whole window the effect of a beautiful picture. No one would think of lighting a picture

by placing bare lamps around the frame, or by hanging a cluster of fancy lamps directly in front of it, and I cannot imagine why these things are done with show windows.

Another advantage of this form is that one is not required to get into the window or disturb it in any way when trimming the lamps.

The store lighting proper may be divided into general illumination and special illumination, such as office, desk, showcase or special lighting needed to display goods during the actual sale. In the example being treated, the store is practically all open or nearly free from the need of special lighting. Our plan will, therefore, be to give the store such general lighting that it will take care of all cases except the office, stairway and blacking-stand.

The location of the seats for trying on shoes, as shown on the plan, is a little off from the center of the store, and it might be considered advisable to light them specially. By giving ample general lighting, this is not considered necessary. The plan shows no reason for not moving them to the center of the room where they would be equally lighted on both sides by the scheme of general lighting in mind. I should recommend this change. Behind the blacking-stand, I should place an inverted No. 13 bracket with a "Reflex" lamp, bypass and a 5-inch ball Verra

Fig. 7. Gas Lamp with Sand-Blasted Cylinder.

Krasna globe with bottom sand-blasted cylinder (Fig. 7). This arrangement would enable one in the chair to read a paper in the accustomed position; that is, with the lamp to the back and left of the reader. The Verra Krasna globe is the best light diffuser of which I know. It appears evenly illuminated on every inch of its surface. Its intrinsic brilliancy is low, on this account, but the absorption is not as great as might be imagined.

being about 10 per cent. more than a French rough or inside sand-blasted globe. It is selected for this position on account of the reader being very close to the lamp, and a strong light would therefore be undesirable.

Figure 8 shows the candle power curve of the "Reflex" lamp with this globe and cylinder, being 70 cp. in the vertical and gradually diminishing to 50 cp. on the horizontal.

The cashier's cage is assumed to have a desk on the long side toward the store front. Probably one cashier is all that would be required and she would probably sit near the end of the office, toward the blacking-stand, in front of the usual cashier's window. Behind her chair, I should install a two-lamp chandelier, 24-inches long, on which would be placed two "Reflex" lamps, bypasses, No. 503 flat shades and bottom sand-blasted cylinders. From this fixture, if both lamps were used, the light would be directed from above and behind her, from her left and from her right. This would reduce shadows from her pen to a minimum. The value for the foot-candles on her desk four feet above the floor, from these two lamps hung 24 inches from the ceiling, would be about 6. This arrangement would be adequate for a second employee sitting at the cashier's right or for the manager, if he had a desk on the side of the room away from the blacking-stand. By having two lamps here, it is possible to light up partially on a bright day, by the use of one lamp, or both may be used as required. Fig. 9 shows the candle power curve of this lamp.

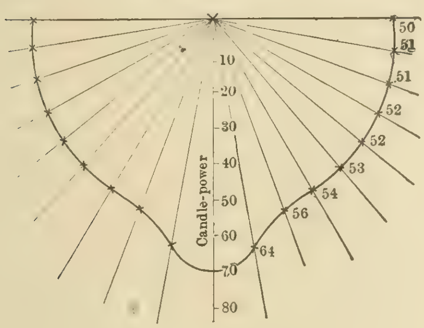


FIG. 8. CANDLE POWER CURVE OF REFLEX LAMP AND VERRA KRASNA GLOBE.

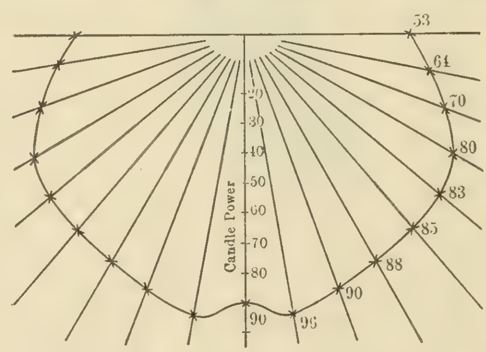
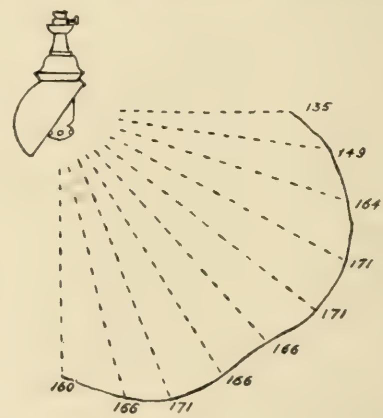


FIG. 9. CANDLE POWER CURVE OF REFLEX LAMP WITH FLAT OPAL SHADE AND SAND-BLASTED CYLINDER.

For lighting the stairway, I have never seen a lamp more satisfactory than one having its rays entirely shielded from the person going down stairs. Most stair accidents are caused by

not properly judging the top step. A lamp throwing a strong illumination on the first step and all the way down the stairs and entirely shielding the eye of the passer is ideal. Such a unit is embodied in the "Reflex" lamp, bypass and No. 445 green-plated angle-shade as shown in Fig. 10. This lamp should be hung seven feet from the floor in which position it would give about 3¼ foot-candles on the floor, directly under the lamp. This is very much more light than is generally found in such



Figs. 10 and 11. Lamp with Angle Shade and Light Distribution.

places. It might be criticized as shining directly in one's eyes, when coming up the stairs, but as a matter of fact one seldom looks up as high when ascending steps, for he is generally looking at the steps just ahead of him and does not get his eyes in the direct range of vision of a lamp thus placed. Fig. 11 shows the candle power curve of this unit.

For lighting the store proper, two plans suggested themselves: First, to place single lighting units at proper intervals so as to get a good distribution. After comparing the appearance of this system in stores actually using it with others using clusters of lamps at less frequent intervals, there was no doubt in my mind which made the better artistic appearance. For this reason, I have chosen a three-lamp chandelier, No. 8714, equipped with "Reflex" lamps, bypasses, No. 503 9-inch flat-opal reflectors and sand-blasted bottom inner cylinders. Fig. 12 shows the fixture in two-lamp form: The fixture should be made 24 in. over all, thus placing the lamps 9 ft. from the floor or 8 ft. above the shoe-fitting stool. The amount of light has been computed on this plane, one foot above the floor. The floor illumination would be slightly less. In a store of this size, it is advisable to place

the lamps as high as possible. This method gives the store an appearance of roominess. With a higher ceiling, I should place the lamps still higher, in order to keep them well out of the range of vision.

The illumination on a plane, 1 ft. from the floor or 8 ft. from the source of light, was calculated for one of the three-lamp clusters, assuming the three lamps concentrated in a single unit. This, of course, is not an accurate method, but the results approximate closely enough for this practical problem. It was found that the value of the foot-candles directly under the unit

FIG. 12. TWO-LAMP GAS FIXTURE.

was 2.8, and dropped off at a distance of 6.7 ft. from the perpendicular, to 1.2 ft.-candles. From this calculation it was believed that the clusters placed approximately 12 ft. apart would give a fair distribution; the curve of illumination as plotted is shown in Fig. 13, which shows the individual curves from two

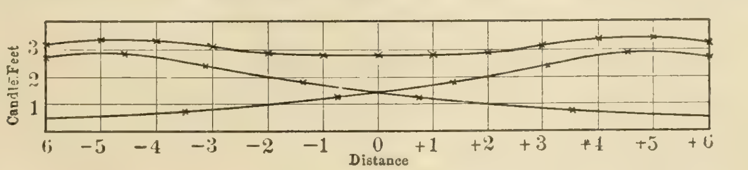


FIG. 13.—ILLUMINATION CURVE OF THREE REFLEX LAMPS WITH FLAT SHADES AND SAND-BLASTED CYLINDERS.

clusters, 12 ft. apart, and also their combined curve. The curve indicates a fair illumination between lamp centres; as approximately 12 ft. was a convenient distance, it was decided to place the lamps accordingly. The store was laid out in 8 rectangles

16½ ft. wide (½ the distance between shelves on either side) and 11½ ft. long (¼ the length of store exclusive of show window). In the centre of seven of these spaces (all except the section occupied by the office) is to be hung a three-lamp chandelier as before mentioned.

Without taking into consideration the increase of illumination through reflection, which would be considerable from buff walls and shelves full of white shoe-boxes, the illumination under a cluster would be about 3.2 foot-candles and midway between clusters about 2.8 foot-candles or an average of about 3.1 foot-candles. Each lamp is an independent unit and one, two or three on each chandelier may be used as desired, each being lighted by simply pulling its chain.

No special illumination has been planned for lighting the shelves. The good general illumination and the excellent reflection are considered ample for enabling one to read readily the figures on the shoe boxes. The illumination on the shelves 3 feet from the floor is about 1½, and 9 feet from floor, 3.18 foot-candles.

By using such a lamp placed 9 feet above the floor, we have a very satisfactory illumination from any standpoint considered. The general effect on the whole is most artistic and pleasing, and from the street the appearance is that of a very brightly lighted store without seeing any large or brilliant individual lamps. I feel that a store should have at least an average of 3 foot-candles of well diffused light on the lighting plane for general illumination. This is necessary to give it the appearance of brightness, cheerfulness and welcome. This is the appearance which pulls and holds customers, sells goods at a profit and brings success.

The total number of lamps to be used are as follows:

Store Proper	21
Blacking Stand	1
Cashier's Cage	2
Stairway	1
Windows	14
	39

Each lamp will consume not over 3 cu. ft. of gas per hour, or a total of not over 117 cu. ft. per hour. The pilot lamps will burn about 1/12 cu. ft. per hour each, or a total for the 25 pilots

of less than 3 cu. ft. per hour. The entire total is 120 cu. ft. per hour. The average hours per day burning generally used for a store is three. Figuring three hours per day at 120 cu. ft. per hour and adding 63 cu. ft. for the pilots for the remaining 21 hours, gives a total of 423 cu. ft. per day for the gas consumption.

This system is very economical from the standpoint of cost of maintenance. No particular effort has been made to reduce the first cost, materials of the best value, in the writer's judgment, having been selected as being the most economical in the long run. It was not laid out with the idea of giving just enough illumination, but I had constantly in mind the advantage to the store keeper of having the store illuminated in such a way that he could, when desired, outshine his neighbors, and at the same time use as much or as little light as he chose.

DISCUSSION OF "THE LIGHTING OF A SMALL SHOE STORE," BY THE NEW ENGLAND SECTION.

Mr. W. H Blood, Jr.—It seems to me that the arrangement suggested by Mr. Allen represents a decided backward step. In the early days arc lamps were used for lighting stores, but they were subsequently discarded on account of their concentrating too much light in single units. The next step was to use electric and gas lamps of small candle power and to separate them, for by so doing a more even distribution of light was obtained. Mr. Allen returns to the principle of large candle powers in single units. The effect of the arrangement on my eyes is unpleasant—it is almost annoying. It is evident that the room is very low studded, but the intrinsic brilliancy of the lamp is so intense that the effect upon the eyes is actually painful. The same number of lamps separated one from another, I think, would not be objectionable. The suggestion to use such an outfit, for the illumination of a small store building comes to me as a matter of great surprise. I cannot see the reason for advocating the use of such a system of lighting in the solution of the problem which is before us.

Mr. J. S. Codman.—I, too, believe that the arrangement proposed by Mr. Allen is open to some criticism. I cannot help feeling that the intrinsic brilliancy is a great deal higher than a properly sand-blasted reflector would make it. Moreover, the unit seems to be too large for use in the store. The illumina-

tion would be more uniform with a large number of units. The unit is too large, just as an arc lamp would be for this installation.

Mr. F. W. Wilcox.—I believe it would be much more satisfactory to use 60-watt or 100-watt tungsten lamps properly distributed and equipped with suitable shades than to concentrate the light in large units.

Mr. R. Robinson.—I had occasion recently to select the lighting equipment for a store 52 feet in length by 31 feet in width. Eight 100-watt tungsten lamps placed 8 feet above the illuminated surface gave an average of 2 foot-candles. I believe the same arrangement used in the store under consideration would produce satisfactory results.

Mr. T. H. Piser.—It is desirable to have a uniform distribution of light in a store. However, what the store-keeper demands is brilliant illumination, and for this purpose a value of 3 foot-candles on the lighting plane is not excessive.

Mr. H. M. Daggett, Jr.—I should like to ask Mr. Allen concerning the lighting of the boot-black stand and the cashier's desk. It seems to me that the lamps in the center of the room would be very trying on the cashier's eyes, while the boot-black stand requires a special lamp. It is very desirable to place a lamp so that men can read with comfort while having their shoes shined.

Mr. Allen.—I have made provision for one 60-watt tungsten lamp near the cashier's desk. At the boot-black stand the illumination averages at least 2.5 foot-candles, and considering the reflection from the walls, it would seem that there is no need for an extra lamp at this place. In regard to the use of four large main lighting units instead of a larger number of smaller units, it should be noted that when there are many lighting sources the retina of the eye contracts and hence the smaller the number of units the better the real illuminating efficiency. The particular units chosen give a good light distribution for illuminating the floor. The absorption is somewhat greater than with opal reflectors, but the real illuminating efficiency is improved by the reduction in intrinsic brilliancy. By using clear lamps the loss of useful life due to frosting has been avoided. The fixtures are so designed

that a current of cool air drawn in at the bottom of the shades is brought in contact with the lamps and passes out through an opening in the fixture casing. Tests have shown that the temperature rise is well within safe limits.

Mr. W. H. Blood, Jr.—The form of window lighting proposed by Mr. Daggett does not appeal to me. Fully 30 per cent. of the light is lost by the use of ground glass. Equally as good effects, and in many ways a superior lighting, can be obtained by means of green shades placed close to the window so that no light will be thrown in the eyes of people on the street. In this way intense light would be obtained on the merchandise in the window.

Mr. F. E. Smith.—I ask Mr. Daggett how the maintenance of the mantles of the inverted gas lamps compares with that of the upright mantles.

Mr. M. M. Jacobs.—I wish to ascertain if there is a plant in operation in Boston using the double-piping system with high-frequency coils, etc., as described by Mr. Daggett.

Mr. W. King.—How close to the ceiling can the inverted gas lamps be placed with safety?

Mr. Daggett.—So far as concerns fire hazard the lamps can be placed within one foot of the ceiling. However, in such a case a shield should be used overhead. I may say that there are now in use in Boston several systems similar to the one described, although none is arranged in exactly the same manner. The jump-spark ignition system has not been installed for regular service, but a demonstration equipment is giving satisfactory results in a show room.

Experience shows that the life of the mantles on inverted gas lamps is about twice that of upright mantles; moreover, they will withstand about twice as much vibration, the costs of the two being equal. In regard to the use of reflectors instead of ground glass shades, it should be noted that while the former produce excellent results in open windows, they are disadvantageous for closed windows on account of the moisture which will accumulate on the glass. Moreover, the diffusing glassware is very effective in softening the light and producing a pleasant result. The absorption, although large, is not prohibitive.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. JUNE, 1908. NO. 6.

At a meeting of the Council, held on June 12, the Secretary read a letter addressed to the Council by Dr. Alex C. Humphreys, Chairman of the Committee on Nomenclature and Standards, giving a report of the action taken by the Committee relative to the establishment of a uniform value for the unit of luminous intensity in the United States. It was moved and duly carried that the Council accept this report with a vote of thanks for the thoroughness and care with which the matter has been carried out, and that they approve the recommendations of the Committee on the subject of a common unit of light.

In compliance with the request of the Council at the preceding meeting, Dr. A. S. McAllister, Chairman of the Committee on Editing and Publication, recommended the appointment of the Chemical Publishing Company, Easton, Pa., as the printer of the *Transactions* of the Society. The Council received this recommendation with approval and referred the matter back to the Committee with power.

The Secretary reported that the following twenty-six applications for membership had been received and properly approved for presentation before the Council. It was voted to elect these applicants:

ADAIR, CLIFFORD FRANK, Electrician, South Side Elevated R. R., Chicago, Ill.

ATWOOD, C. C., Assistant Superintendent, New Amsterdam Gas Co., Ravenswood, L. I.

BECK, FRITZ, Secretary, Pneumatic Gas Lighting Co., 150 Nassau St., New York.

BENSON, FRED S., JR., Supt., Nassau Works, Brooklyn Union Gas Co., Brooklyn, N. Y.

BERRY, ALFRED F., United Electric Light & Power Co., 1170 Broadway, New York.

BROCK, JOHN M., Sales Manager, William M. Crane Company, New York.

BRYAN, F. A., General Manager, Indiana & Michigan Electric Co., South Bend, Indiana.

CARTER, R. A., JR., Asst. Engr., Central Union Gas Co., New York.

DAVIDSON, J. E., President, Consolidated Lighting Co., Montpelier, Vt.

DUTTON, BENJAMIN H., Asso. with Edward Miller & Co., Philadelphia, Pa.

HALL, A. H., Supt. of Distribution, 1815 Webster Ave, New York.

HARE, C. W., Manager of New Business Dept., United Gas Improvement Co., Philadelphia, Pa.

KEENE, A. M., Comptroller, Westchester Lighting Co., Mount Vernon, N. Y.

KENNEDY, JAMES S., Superintendent, Standard Gas Light Company's Works, Foot East 115th St., New York.

MACINTOSH, W. L., Engineer's Assistant, Consolidated Gas Co., New York.

MACKLIN, A. F., Superintendent's Assistant, Consolidated Gas Co., Foot West 44th St , New York.

McCLELLAN, JOHN W., Vice-Pres. and Gen. Manager., Manhattan Gas Heating Co., 909 Seventh Ave., New York.

MORÁ, E. J., West Penn Railways Co., Connellsville, Pa.

OPDYKE, GEORGE H., President, Rector Gas Lamp Co., 47 Leonard St., New York.

PETTIT, LEWIS A., JR., Salesman, Commonwealth Power Co., Jackson, Mich.

REID, J. F., Standard Gas Light Co., 32 West 125th St., New York.

REINACH, H., Asst. Supt., Standard Gas Light Co., 32 West 125th St., New York.

RIBLET, A., Superintendent 14th Street Station, Consolidated Gas Co., New York.

SHAW, JOHN C., Engineer, Astoria Light, Heat & Power Co., Astoria, L. I.

WALMSLEY, W. N., General Manager, Sao Paulo Tramway, Light & Power Co., Ltd., Sao Paulo, Brazil.

WILTSE, JAMES LAWRENCE, Chief Clerk, Contract Dept., Edison Electric Illuminating Co., Brooklyn, N. Y.

The Chairman of the Finance Committee presented the Committee's report on the financial condition of the Society, and submitted the unpaid bills, amounting to $641.48. The Council approved this report, and directed that the bills which were submitted, be paid.

It was moved, that the Council on hearing the report of the

Finance Committee offer the suggestion that, so far as possible, all of the expenses of the Convention, with the exception of the expense of printing and distributing the Convention Number of the *Transactions,* be paid from the Special Convention Fund collected by the Convention Committee. This motion was seconded and carried.

Vice-President Mohr submitted to the Council the method of handling the Convention Fund as proposed by the Convention Committee. The Council moved to endorse this method.

It was moved, and duly carried, to approve the action of the Convention Committee in fixing the dates of the Convention as October 5 and 6,—Monday and Tuesday.

A suggestion was offered, which was duly accepted by the Council, that the Secretary ask the Chairman of the Convention Committee to furnish a brief report of the Convention arrangements, with a preliminary list of the papers to be presented, and that this report be published in the Society Notes of the June Number of the *Transactions.*

ANNUAL CONVENTION.

The second annual Convention of the Illuminating Engineering Society will be held in Philadelphia, on Monday and Tuesday, October 5 and 6. The General Convention Committee is busily engaged at the present time in making plans and arranging details with the expectation of preparing a program which will make attendance upon the Convention not only entertaining but valuable for every member of the Society.

Monday and Tuesday were considered the best days of the week upon which to hold the Convention for the reason that the members who attend from distant localities are able to leave their places of business on Saturday or Sunday, thereby not losing time, and the Committee also considered the fact that members might desire to avail themselves of the opportunity of

spending the week end at Atlantic City, or at some of the other resorts within a short distance of Philadelphia.

The Headquarters of the Convention will be at the Hotel Walton, centrally located, at Broad and Locust Streets. Sessions will be held in a large auditorium on the top floor of this hotel. The convenience of holding all meetings in the same building in which the delegates live is apparent, and this arrangement will avoid much waste of time. Notice concerning hotel fares and other details will be sent to the members by the Committee in a short time.

It is hoped to have an exhibit of modern methods of illumination and illuminants with their accessories, together with the various scientific and measuring instruments used in the lighting industries, and if this exhibit is found feasible it will be given in a hall adjacent to the auditorium in which the regular sessions are held.

Full announcements concerning the program of business and entertainment will, of course, be sent to each member. The week of October 5 to 10 will be Founders' Week in Philadelphia, and great preparations are being made by the Municipality to make the occasion notable. The entire week has been set aside to celebrate the 225th anniversary of the founding of Philadelphia. There will be various interesting ceremonies. On one day there will be a military parade of Regular and State Troops; one day will be set aside as Municipal Day; another as Industrial Day, and so on.

This season of the year in Philadelphia is usually most pleasant, from the standpoint of temperature; and as is well known, Philadelphia abounds with points of historic interest, second to no city in this country.

CONVENTION PAPERS.

The following tentative list of papers has been arranged for:

"Architecture and Illumination," by Mr. Emile G. Perrot, Philadelphia.

"Modern Gas Lighting Conveniences," by Mr. T. J. Litle, Philadelphia.

"Railway Car Lighting," by Mr. H. M. Davies, Philadelphia.

"Relation Between Candle-Power, Voltage and Watts of Different Types of Incandescent Lamps," by Dr. F. E. Cady, Washington, D. C.

"Illuminating Value of Petroleum Oil," by Dr. A. H. Elliott, New York.

"Structural Difficulties in Installation Work," by Mr. Strong, New York.

"Street Lighting Fixtures, Gas and Electric," by Mr. H. Thurston Owens, New York.

"Oil Burners," by Mr. W. T. Sterling, New York.

"Design of the Illumination of the New York City Carnegie Libraries," by Mr. L. B. Marks, New York.

"Intensity of Natural Illumination Throughout the Day," by Mr. L. J. Lewinson, New York.

"Calculation of Illumination by Flux of Light Method," by Messrs. J. R. Cravath, Chicago, and V. R. Lansingh, New York.

"Specific Intensity of Lighting Sources," by Mr. J. E. Woodwell, Washington, D. C.

"Design of Reflectors for Uniform Illumination," by Mr. A. A. Wohlauer.

"The Ives Colorimeter in Illuminating Engineering," by Dr. H. B. Ives, Washington, D. C.

"International Unit of Light," by Dr. E. P. Hyde, Washington, D. C.

"Some Experiments on Reflections From Walls, Ceiling and Floors," by Messrs. V. R. Lansingh and T. W. Ralph, New York.

It is possible that one or two of the subjects, and possibly a few of the authors of these papers, may be changed, but the Committee on Papers hopes to provide the program indicated.

CHICAGO SECTION.

The last meeting for the present season of the Chicago Section was held Thursday evening, June 11, at the Grand Pacific Hotel, fourteen members being present. J. R. Cravath, Chairman, presided. The Secretary announced four new applications for membership since the last meeting.

Appreciation was expressed for an invitation from the Iowa District Gas Association to the Society to attend their annual meeting in Omaha, June 17.

Dr. Suker distributed copies of a recent paper by Dr. Chas. E. Woodruff, of the United States Army, the paper being entitled, "Insufficient Pigmentation as a Cause of Eye Diseases." Dr. H. Gradle of Chicago delivered an address, the subject of which was "Illumination and the Eye." Many important points were brought out and a general discussion was entered into by the members present.

NEW ENGLAND SECTION.

At a meeting of the New England Section held on May 27, a problem relating to the illumination of a large retail dry-goods store with show-windows was offered for solution. Solutions were presented by Mr. J. S. Codman who suggested the use of tungsten lamps; by Mr. N. W. Gifford who advocated gas "arc" and inverted gas lamps, and by Mr. Newington who selected Nernst lamps.

The last meeting of the present season was held on June 19, when Mr. H. M. Daggett, Jr. read a paper entitled, "High Efficiency Illuminants." This paper, together with the discussion which its presentation aroused, will be printed in the October issue of the *Transactions*.

CHURCH LIGHTING.[1]

BY EMILE G. PERROT.

Co-operation among engineers and architects is essential to the ultimate success of any building, whether the problem be one involving a lighting scheme, or a scheme of structural engineering and architecture, or any other. In other words, the aesthetic and the practical must go hand in hand. In presenting to you the aesthetic side of this problem, it is my desire to do so in a light in which possibly you have never viewed it before.

From the very beginning light has played a most important part in the life of the world; shut out light from any living thing, plant, brute or man, and part of life itself is taken away. As light is necessary to the fullness of physical life, in like manner the spiritual life of man craves as its perfection, spiritual light.

The old law prescribed a seven-branch candlestick as part of the sacred treasures to be kept before the eyes of the people; when Christ came he voiced the need of men's souls when he proclaimed: "I am The Light of the World." As a symbol of Him, the Light of the World, the early Christians lit candles in the dark chambers of the catacombs; symbols these lights were indeed, but they served the added purpose of illumination.

So then, the architect, whether designer of lofty cathedral or lowly church, must consider light both symbolic and illuminant.

In the Dark Ages, the great cathedrals were content with "the dim religious light" that Milton speaks of, coming through the rich colors of the great stained glass windows. In the advance of science, religion caught the benefit and flooded its temples with the imprisoned sunlight let free from coal or oil. When later, electricity was employed, religion seized the new light to serve its purpose.

That we may understand the "raison d'etre" so to speak, of symbolism in the church, it will be well to consider briefly the subject of symbolism in art and the principles which underlie it, and which give it the importance it deserves. Art does not

[1] Read before the Philadelphia Section of the Illuminating Engineering Society, on April 24, 1908.

produce the real; it merely implies or suggests the real by the use of certain signs and symbols which have been recognized as equivalent. If, for example, we wish to bring to the mind of another the thought of water, we do not bring a glassful and place it before the person; we simply use the word "water," a word of five letters, which bears no resemblance or likeness to the real article, yet brings the original to mind at once. This is the linguistic sign for water. The chemical sign for it, H_2O is quite as arbitrary, but to the chemist represents the original as clearly as the word does to the mind of another. And only a little less arbitrary are the artistic signs for it. The old Egyptians conveyed their meaning by drawing a zigzag line up and down the wall. Turner, in England, often made a few horizontal scratches from a lead pencil do duty for it, and in modern painting we have some blue or green paint touched with high lights to represent the same thing. None of these symbols attempt to reproduce the original, or have any other meaning than to suggest it. They are signs which have meaning because we agree beforehand thus to understand them.

Now, the agreement to understand the sign is what might be called the recognition of the convention. All art is in a measure conventional, arbitrary, unreal, if you please. Everyone knows that Hamlet in real life would not talk blank verse in his latest breath. The drama, and all poetry, for that matter, is an absurdity if one insists upon asking "Is it natural?" It is not natural; it is artificial, and unless the artificial be accepted as symbolizing the natural, unless the convention of metre and rhyme be recognized, one is not in a position to appreciate verse. And this is equally true of music. The opera is a most palpable convention, and the flow of music which so beautifully suggests the depths of passion and the heights of romance, is merely an arbitrary symbol of reality. Recognize this and you have taken the first step forward toward the understanding of art; fail to recognize this, and art must remain a closed book to you.

Furthermore, the principle of indirectly representing by a sign the Godhead or the truths which He came to establish, had its sanction in the Divine Master Himself, for in his own public life He continually makes use of parables and indirect means to

convey to his followers the divine lessons He wished to teach.

Religion, as we know it in the twentieth century, has formed itself into two great bodies, which we may term the evangelical and ritualistic. To light a church so that the lamps may serve the practical purpose as illuminant, and at the same time keep the religious symbolism in the spirit of each of these great divisions, is the problem of church lighting that I propose to discuss.

The evangelical church holds specially to the Scriptures, and

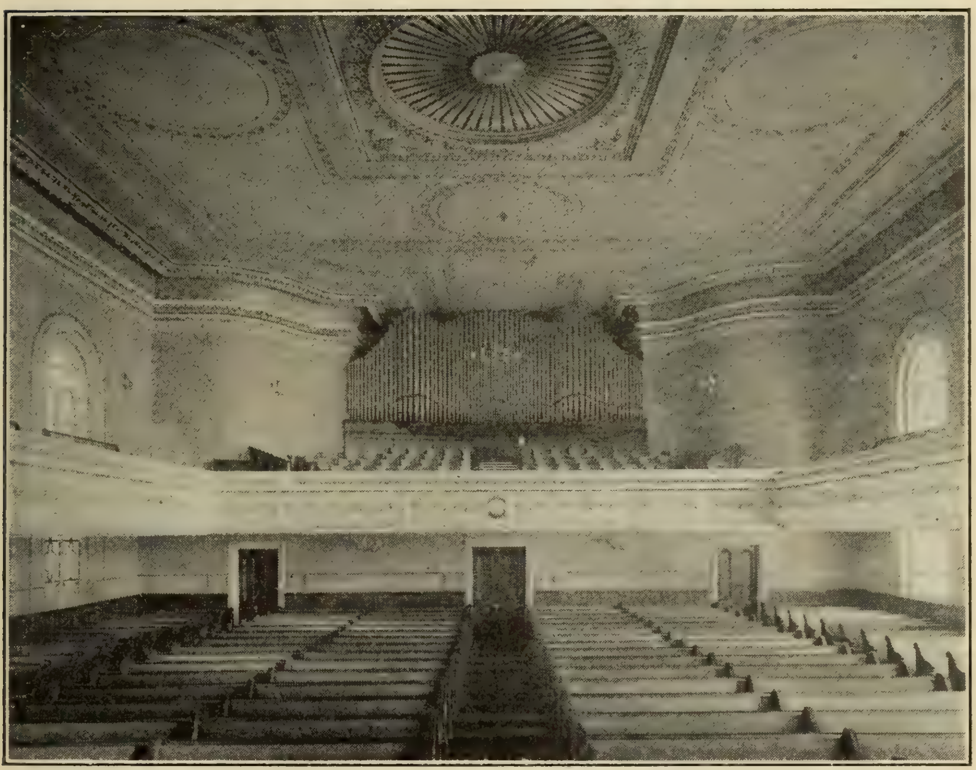


Fig. 1.—Evangelical Church. Ineffective Lighting Scheme.

the keynote of its service is the spoken word of the expounder of the Holy Book. So light must fill the auditorium, must center on the preacher, as symbol of the Heavenly Light that he teaches, filling men's souls.

In the other great division, a subdued light must envelop the congregation as befits those attending on great mysteries, and the light must center on the altar, shining against the darkness of the background, appearing above all else in the church, as symbol of the Light of Heaven resting on the mysteries.

Thus we have, in general, the thought underlying the scheme of lighting for churches of both divisions.

While it may not be possible to show practical examples of

Fig. 2.—Evangelical Church. Highly Successful Lighting Scheme; Electric Lamps are Used in the Ornaments on the Arches.

lighting that exactly illustrate the principles enumerated above, yet in the main, we will find these principles carried out to a greater or lesser degree in all well arranged churches. Of

course, the architectural treatment of the design will influence the scheme of lighting, but the architectural scheme should follow the above principles, just as the lighting is intended to do;

Fig. 3.—Ritualistic Church. Chandeliers in Center of Nave Vault Destroy Clear View of Vault.

for instance, the plan of evangelical churches naturally takes a form best calculated to permit every one to see and hear the speaker, hence there are large auditoriums so designed as to

meet these requirements. On the other hand, the plan of ritualistic churches aims not so much to make a perfect auditorium, as a place first for the altar, about which the people may gather to take part in the solemn sacrifice which is offered thereon, the part played by the speaker being second in importance to the great mysteries of the sacrifice.

Further, the ritualistic ceremony naturally begets symbolical forms in the architectural treatment, so that there are depicted throughout representations of the great mysteries of religion, both in the structural parts and in the minutest details.

As the problem of lighting evangelical churches resolves itself into that of general illumination, the treatment of such buildings can best be made to follow the general rules recognized as a standard for the lighting of auditoriums; a few examples will serve to make the matter clear.

The problem of lighting ritualistic churches, particularly Roman Catholic churches, is one that requires more study since the predominance of the symbolical over the practical is very marked. There is an added problem in these churches of decorative lighting in addition to the practical and symbolic lighting. This of late years, has become very marked, due to the ease of obtaining decorative effects with the use of the many sizes and styles of electric lamps. A scheme for lighting for a Catholic Church which does not include facilities for decorative lighting around the sanctuary where the altars are placed is incomplete. While the use of candles on the altars is required by the rubrics of the church, and they must be used, the added use of electric and gas candelabra makes it possible to obtain decorative effects in light for celebrations which far surpass the effect of the candle light.

One reason why electric decorative lighting has come into play in this church is due to the fact that as the church proper was lit by electricity, the insignificance of the illumination of the altar by candles alone became very apparent, and as the altar is the object for which the church exists, and in its symbolical sense, should be the richest part of the church, it was necessary to add electric illumination to this part of the church also.

To come now to the actual working out of these principles

to concrete problems, it would be well to endeavor to establish rules for guidance which can be used in most cases. In examining the general form of evangelical churches, it is found that

Fig. 4.—Ritualistic Church. Showing Proper Arrangement of Lighting Fixtures Along the Nave Walls, Thus Permitting Clear View of Vault.

in plan they may be grouped as follows: Square plan; Rectangular plan, and Greek Cross plan, all usually consisting of one clear span. The church may or may not have a gallery, but as

a rule, the floor area in the center must be illuminated from the high ceiling above. Usually it is preferable to hang chandeliers from points each side of the centre of the building. The use of central chandeliers is, as a rule, an unhappy solution, and should be avoided unless the architectural treatment of the ceiling is such as not to permit of the use of two rows of fixtures; then the use of one row or one central fixture must be resorted to.

The lighting of the chancel should be such that ample light

Fig. 5.—Ritualistic Church. Illustrating Effective Use of Two Rows of Fixtures Suspended from the Ceiling.

falls on the preacher. Should there be a chancel arch, concealed lamps around the arch produce a very impressive effect.

Should a gallery be used, the part of the church under the gallery can best be lit by ceiling lamps under the gallery, or lamps can be arranged around the columns near the caps. If there is no gallery, side lamps on the walls are sometimes necessary to supplement the light from the ceiling. There is no reason, though, why ample light cannot be arranged for in the ceiling. The one point to bear in mind is not to have naked

lamps in line with the vision of the congregation. The use of brackets with naked lamps on the wall back of the chancel is injurious to the eyes of the people, and should be avoided.

Should there be a dome or skylight in the center of the ceiling, rows of lamps arranged to suit the architectural motives can be used instead of ceiling pendants. When open truss work occurs, the fixture should be suspended from the trusses.

A very effective method of lighting a decorated ceiling is to conceal the lamps on top of a cornice and project the rays upwards; if there is no cornice, the top of column capitals can be built with a recess to receive a number of lamps and the light projected from these points.

Very frequently it is possible to light the auditorium without the use of ceiling fixtures, dependence being placed on lamps around the walls; while the use of ceiling pendants seems to be a popular method of lighting, it very frequently happens that a clear view of a very beautiful ceiling is interrupted by unsightly chandeliers.

Turning next to the lighting of ritualistic churches, the problem is found more complex. As outlined above, symbolism plays an important part in the design of such churches, so much so as very frequently to determine the shape of the floor plan. The cruciform plan is the one most generally used for large churches, consisting of a nave and two side aisles across the church, and the nave transepts and apse for the three divisions of the length of the church. Of course, all churches do not have side aisles, nor do they all have transepts, but this form of floor plan is symbolically correct, as it represents the emblem of salvation, namely the cross.

Formerly the common method of lighting was to arrange pendants from the apex of the main nave arch, thus making a row of chandeliers in the middle of the church. The side lamps were usually arranged around the columns or piers, sometimes in the form of a corona, and sometimes as brackets.

With the advent of electric light, greater freedom of arrangement of the lamps became apparent, hence marked progress was made by arranging rows of electric lamps in cornices or other

architectural features, doing away with the need of chandeliers. However, a combination of chandeliers and cornice lamps has

Fig. 6.—Ritualistic Church. Decorative Lighting for Christmas Celebration. Floral and Electrical Effects.

become very common, due to the marked decorative effect of outlining the main architectural motives by means of lamps.

This arrangement was even attempted in former days with gas lighting.

The arrangement of lamps about the sanctuary where the altar is placed requires the utmost care, each individual church being a law unto itself; while it is possible to outline general rules to be observed for lighting this part of a church, the problem usually demands more than the science of an illuminating engineer, coming more under the head of decoration.

For instance, in Catholic Churches, there are certain services and parts of the service which require special lighting effects, due to the season of the year, the nature of the services and whether the Blessed Sacrament is exposed or not. For grand celebrations, such as the present centenary of the Diocese, special decorative effects in lighting and decoration with plants and flowers is resorted to. In one service of the church on Good Friday, there is a part where total darkness reigns for a few seconds, and then instantly a flow of light fills the church. While it is not the desire of the church in any way to attempt theatrical effects, it is the intention to make the exterior signs an expression of the interior feeling one should possess in attending the service. As all of these services are to be performed in a strictly lithurgical manner, it is a very delicate matter to introduce effects in lighting which will not destroy the real meaning of the service.

Modern development of lighting, when considered as a part of the architectural scheme, has led to the placing of the bulbs or lamps in some ornament in the design of the building, instead of making a separate ornament in the form of a gas or electric fixture. While this method does away with the costly fixtures, it may on that account not be much encouraged by certain interests, in the same manner as some interior decorators bewail the loss of large plain surfaces in churches upon which they can paint architectural features such as niches, panels, mouldings, etc. Real art does not consist in imitation, hence the true method of architectural expression is to make the panels, mouldings, etc., out of the material of which the building is being finished. If it is too costly to do this, the proper procedure is then to omit what cannot be provided in the real materials. If

decoration is desired, the large areas can be treated as such with simple borders, etc., to relieve the plainness.

Rosettes are very suitable ornaments for the introduction of lamps; a lamp can be put in the center of the rosette and the leaves surround the lamp. The arrangement is well adapted to the rosettes in the soffit panels of classic cornices or panels in the soffits or arches. Any such adaptation of lamps to permanent ornaments brings in the decorative effects of electric lighting, as well as its practical result as illuminant.

DISCUSSION OF MR. PERROT'S PAPER BY THE PHILADELPHIA SECTION.

Mr. A. F. Mayers:—Mr. Perrot has suggested some new thoughts to me. In the churches we have an opportunity to demonstrate the value of good illumination. There is nothing more pleasing than to sit in a church in which the illumination is just exactly what it should be. The paper by Mr. Perrot will open up some new ideas and possibly suggest some better schemes of illumination, not only in the churches of to-day, but in the churches of the future.

Mr. Carl Hering:—With regard to the illumination of the face of the person who is addressing an audience in order that the expressions of his face may be more clearly seen, it is to be noted that it is very necessary to see the contours; thus it is necessary to have shadows. Hence diffused illumination in front of a speaker's face, or illumination from a number of scattered lamps would be ineffective, because neither of them throw shadows; in such illumination the face would be likely to be equally illuminated all over and would therefore look flat and the expression would be lost. The same would be true for a strong light from a reflector directly in front of the speaker, as is frequently used in theatre lighting. The other extreme is a single strong beam of light from one side which gives too great a contrast between lights and shadows in the face, producing a sort of Rembrandt effect. It seems to me, therefore, that to illuminate a face most effectively, we should study the practice of photographers in making portraits, as the photographer has studied the question of bringing out the features of the face more care-

fully than any one else. It seems that he uses a certain amount of diffused light coming from a limited direction together with some small white reflecting surfaces to accentuate the light from one particular direction above and to one side of the face, so as to produce shadows but without having any sharp contrasts between lights and shadows.

One of the points raised in the paper appealed to me more especially because there seems to exist a misunderstanding about it; I refer to the advantages of indirect illumination, that is, illumination from concealed lamps. We all realize that this is a more beautiful and effective form of illumination, but it is generally supposed to be more expensive, because the reflected light is so very much less than the original light. While it is true that there is a great loss of light, there is another factor which enters and which I do not think is considered as much as it should be, and which may in many cases overbalance the loss. Illumination is only for the purpose of permitting us to see something with out eyes; if we were all blind, there would be no need of illumination; the better we can see details, the more effective is the illumination. When there is a bright naked lamp in front of our eyes the pupils contract and therefore the eye takes in less of the light and we do not see the things that are illuminated as clearly as we may do with less light and a wide open pupil. Hence the fact that there is less light with indirect illumination does not necessarily mean that we see less, but on the contrary we may really see better. In many cases I am sure we would see more clearly with the subdued diffused light from indirect illumination than with bare lamps glaring in our eyes, on account of the action of the pupils of our eyes. Therefore indirect illumination, as Mr. Perrot has pointed out, is not only more aesthetic, but even enables us to see better. In other words, although the actual illumination measured in foot-candles would be far less, the things that we see with wide open pupils, are made even more clear, than with fewer lamps shining directly into our eyes and thereby contracting the pupils. I think, in the future, although we may not live to see it, illumination will be obtained from large areas of low brilliancy, as from large phosphorescent or fluorescent surfaces instead of from small filaments or arcs of intense brilliancy, according to the

practice of to-day. The use of concealed lamps is a step in this direction, though at the sacrifice of much light. When we learn how to produce such low brilliancy surfaces directly, instead of indirectly by reflection from intense lamps, it will probably be found to be a much cheaper form of illumination besides being more effective in most cases.

Prof. A. J. Rowland:—Church lighting presents some unusual problems. I have not been in an evangelical church yet where I thought the lighting was right. Usually an arch at the platform is put too far behind the speaker to be of any value for use with concealed lamps, or it is nearly directly above the speaker's head where the lamps cast shadows. Sometimes the lamp is under the nose of the speaker sending a glare into his face.

It is a difficult problem to light the face of a speaker properly; I do not know that it can be done very well. I saw a room sometime ago where the problem was solved in the following manner: The ceiling of the room was about 15 ft. high, and there were two groups of lamps placed somewhat at the side and near the ceiling. They were arranged in a line with the front edge of the platform, so that the lamps were just in front of the speaker. Although I did not see the effect at night, it seemed to me that the equipment would light the speaker very well and illuminate anything that he wanted to read.

Another matter that seems to me must be considered in church lighting is the expense, which is an important factor for perhaps 80 per cent. of the churches. Anything in the way of art glass upon or around the fixtures cuts off the light and increases the expense. Thus artistic and churchly effects are apt to make the lighting expensive. While I believe in good and beautiful church lighting, it is well to beware of such things as stained glass which decorators like to use, because good lighting is hard to procure when it is used.

Another thing of importance is the brilliance of light in churches. In some churches where many lamps are provided never more than half of them are used. Sometimes also the controlling apparatus is placed in such an awkward manner that it is impossible to control the lamps without startling the congregation and attracting too much attention.

Mr. C. O. Bond:—In the Market Square church in Germantown provision is made for lighting the speaker. The fixture stands out with graceful curves from the side of the building, so that a hemispherical silver globe is directly over the speaker's head; it is so canted forward that no light shines in the eyes of the audience, but the speaker has a very bright light cast upon him. If the preacher speaks in an eloquent, impassioned strain, I can easily see that when he is warmed up to his subject, it is exceedingly important to properly light his face.

In the latter part of his paper, Mr. Perrot spoke rather apologetically in using the word "theatrical" in regard to church lighting. Now, the word "theatrical" is one at which we have come to look askance, yet, the spirit of this age is to give maximum effect to whatever we do, and if the lime-light on a speaker's face will better serve his purpose to drive home a moral truth, we should use it.

Mr. Walton Forstall:—Mr. Mayers said that we have a great opportunity to improve church lighting. I do not know of any one thing that needs more improvement. There are many old churches which will stay old for a long time, and I do not know of any better suggestion than to persuade some of the members of the Boards of Trustees to improve the lighting, or rather to let us do it. In churches that already exist a great deal of good can be accomplished with little expense.

Mr. E. G. Perrot:—I wish to second what Mr. Hering has said in reference to a lower degree of illumination for church lighting, by the use of a system which does away with fixtures that allow the naked lamps to be exposed to the eye. I know from practical experience the strain of naked lamps on the eyes; in certain position it is impossible to see the centre of the altar because the lamps are on top of the pews and just at the level of the eye, and thus interfere with a clear view of the altar. It is impossible to see the other end of the church through these naked lamps, while if those same lamps were arranged on each side of the church so as to make general illumination, although certain parts would not be lighted nearly as brightly as they are now, the effect on the congregation would be almost perfect. As Mr. Hering says, a bright light contracts the pupil of the eye, while if the light is dimmer, the pupil will expand and put

the owner more at his ease. I am glad he brought out that thought; it is just these considerations that will lead the illuminating engineer to rearrange his schemes of lighting. People should not be compelled to look through lamps in order to see what is taking place farther on.

Regarding what Professor Rowland has said with reference to lighting the face of the speaker, I had hoped that this problem would be solved here tonight. I think that such a scheme as his, if carried out, would lead to a successful solution. As it is necessary to have a bright light on the speaker, I do not see any objection to suspending lamps from the ceiling or putting them on standards, or arranging them in any other way that will throw light on the speaker, provided the desired result is obtained and the naked lamps do not shine in the eyes of the congregation. Art will come to your aid in enriching the bald construction of the fixture, or whatever it happens to be, and will lend its influence to enrich the dark side of the fixture. Whether the solution of the problem is to have a higher foot-candle of illumination, or to project light on the speaker, will have to be determined by experience.

IMPROVEMENT OF EXISTING ILLUMINATION ARRANGEMENTS IN SMALL STORES.[1]

The subject of improving the illumination of small stores and residences with a minimum amount of change in existing arrangements was discussed by the Chicago section, at its May meeting.

Mr. E. W. Lloyd:—In order to compete with the indoor and outdoor electric arc lamps and so-called "gas arcs," the Commonwealth Edison Company is making use of a type of cluster, which consist of four 60-watt lamps with a flat porcelain reflector. The object of using four lamps is to protect the customer. If the fixture had only one lamp it would be a serious matter if it burned out during the evening. The small storekeeper is steadily increasing his demand for light, especially in large cities where his competitors force him to use more light. The tungsten lamp will help electric lighting companies, as the Welsbach mantle has helped the gas company. These clusters are put out in two ways—one whereby the lamps are in use during specified hours and charge a flat price for energy and lamp renewals and maintenance of the cluster; the other proposition is on a meter basis. The number of hours' use per month of a cluster may be determined by means of maximum-demand meter reading, and a rental charge for maintenance is made which varies according to the number of hours the cluster is used. Customers are not expected to touch the lamps, which are controlled by the company.

Mr. George Harvey Jones:—In equipping old residences for electric light, in the majority of cases the customers wish combination fixtures. One must also take into consideration the tungsten lamp. There are plenty of combination fixtures on the market, but I have seen none with which the tungsten lamp can be properly used, because this lamp should be placed up high to get the best results. I have designed a fixture which I believe meets the conditions. In this fixture the tungsten lamps

[1] Topical discussion by the Chicago Section, May 14, 1908.

are placed at the ceiling and the gas jets are on an extension coming up from the center of the ceiling fixture and dropping down low enough so that the gas will not injure the ceiling. The fixture is so made that the gas extension may be readily taken off and capped, if the customer decides to use electricity exclusively.

Mr. M. C. Beebe:—One might arrange a couple of inverted gas burner outlets near the ceiling, where you suggest the use of the tungsten lamp.

Mr. Lloyd:—What is the smallest candle-power of inverted gas lamp?

Mr. Beebe:—About 20 candle-power, consuming 1.5 cubic feet per hour.

Mr. W. R. Bonham:—With gas at 85 cents per 1000 cubic feet and electrical energy at 14 cents per kw-hour, electric light costs eight times as much as gas light if incandescent lamps, taking 3.5 watts per candle are used. As a compensation, however, more of the light is given downwards with the electric lamps, and they will probably be switched on and off more frequently, so that for the same service one would not have the same number of hours of burning. In regard to lighting bills, there are only two in my family, and while we have all the light we wish, the bill for the past month was only 80 cents. If a man will take advantage of high-efficiency lighting arrangements, his bills will be low.

Mr. J. R. Cravath:—How close to the ceiling may one place an inverted gas burner with safety? A plan I have in mind is to place clusters of inverted burners in a certain installation about 2 feet from the ceiling, to be used for breakdown service when electric light gives out.

Mr. Beebe:—Whether a mantle is in constant use or not, it requires attention. I think the best results from gas lighting are obtained when the clusters can be kept in order for constant use. I fear one would not be justified in putting mantles on burners for breakdown service.

Mr. Charles Wing:—It would be safe to put burners 18 inches from the ceiling for emergency purposes.

Mr. C. R. Gilman:—I can say in the matter of using gas as an auxiliary that there are a number of passenger cars equipped

with four inverted burners in addition to four electric lamps on the same fixture and the gas is used for auxiliary purposes entirely. The breakage of mantles, etc., has been very slight and the service satisfactory.

Mr. J. R. Cravath:—The distribution of light from inverted gas mantle burners is very similar to that from tungsten lamps with bowl reflectors. In using tungsten lamp clusters for the general illumination of a store or similar room it is very important for obtaining maximum efficiency to avoid the use of flat reflectors which allow much light to be given off horizontally, which could be utilized to better advantage if given off at some lower angle. In a store a moderate illumination is desired on ceilings and high sidewalls, but most of all strong illumination is needed on the goods in the lower part of the store at and near the counter level. The use of a tungsten lamp cluster with lamps projecting down below an approximately flat reflector is bad, not only because of the blinding effect on the eye, but because too large a proportion of the total flux of light is thrown on the high sidewalls where it does a minimum amount of good. There is no reason why the flat reflectors cannot be replaced by a dome-shaped reflector, which will cover the lamps and so protect the eyes and at the same time deliver a larger percentage of the flux of light from the lamp where it is most needed. With proper density of opal, enough light can be let through for the satisfactory lighting of high ceilings and sidewalls.

OLD CHANDELIERS.

One of the commonest problems met with in residence lighting is to get more useful illumination from the typical old-fashioned chandelier with lamps at an angle of 45 degrees, usually equipped with bell-shaped shades. Besides being one of the commonest, this is one of the most difficult conditions to deal with. In some cases it is possible with care to bend the chandelier arms so as to point the sockets straight down. When this is done, any one of a number of different kinds of reflectors which will give an efficient distribution of light over the lower part of an ordinary small living room can be used. Assuming that the lamps are rated at between 8 and 20 candle-power, among the opal reflectors available are the 7-inch and 8-inch opal domes and the

6-inch, 7-inch and 8-inch fluted opal cones, which are staple trade articles. If tungsten lamps are used, the best reflector I have found for a condition of this kind in a living room is a deep bowl-shaped prismatic reflector with heavy white enamel which diffuses the intense light from the tungsten filament so successfully as to give the appearance and eye comfort of a dense opal. At the same time, it is fairly efficient as a reflector. It should always be used with a special shade holder which brings the reflector about 1 inch lower than the standard shade holder. It is not permissible if one has any regard for eye comfort to put a tungsten lamp at the ordinary height of the chandelier in a small living room, unless it is covered by some such deep diffusing shade as this.

If the arms on the chandelier cannot be bent and the sockets must remain at an angle, there is no very satisfactory way of making a marked increase in the amount of useful illumination in the lower part of the room without introducing with it objectionable glare. If one puts on fairly concentrating reflectors discomfort will be caused to anyone who sits facing the chandelier. Not only will the lamp filament be visible, but the reflected light will add to the glare. The only way I have found to increase the illumination in the lower part of the room and at the same time to reduce the glare with lamps at an angle is to equip the chandelier with prismatic enclosing globes. These enclosing globes give as concentrated a distribution as can be obtained with an enclosing globe, although the percentage of light delivered below the horizontal is not so great as with efficient reflectors. The light is, however, well softened and diffused. The enclosing globes are rather heavy for use at an angle. In order to secure better light for reading, the owner of such a chandelier is frequently willing to hang a lamp with a suitable deep reflector on the chandelier by means of a short piece of drop-cord plugged into one of the sockets. This is a makeshift, but it permits the use of the tungsten lamp where it could not otherwise be used.

REFLECTORS ON CEILING RECEPTACLES.

On old and new work it frequently happens that a ceiling receptacle is provided of the composition-ring type which does not

permit the use of a shade holder without danger that the ring will melt and let the glassware fall. Again use is sometimes made of flush receptacles, upon which there is no possibility of placing a shade holder. The illuminating engineer frequently finds it desirable to use reflectors on such receptacles. Frequently, also, a pendant switch is desirable. Especially is this true in connection with tungsten lamps where it is desired to place the tungsten lamps high against the ceiling to displace lamps formerly used on low drop-cords. In order to get a shade holder on such receptacles and also to permit the use of a pendant switch, I have used a tap which is practically a combined extension plug and socket with bushed opening for a pendant switch.

SMALL STORES.

An arrangement frequently found in country and suburban stores is a row of incandescent lamps over each counter, the lamps usually having no reflectors except possibly small, flat opal reflectors. This situation is very easily dealt with at small expense. The drop-cords can be shortened so as to bring the lamps to 8 ft. above the floor. If 16-c. p. lamps are retained, the fluted opal cone reflector is one of the best to use. If larger, higher-efficiency incandescent lamps are installed, correspondingly large reflectors must be used, preferably of the bowl type.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. OCTOBER, 1908. NO. 7.

A special meeting of the Council of the society was held on Thursday, September 24, there being in attendance President Bell and Messrs. C. H. Sharp, L. B. Marks, A. H. Elliott, C. O. Bond, W. H. Gartley, G. R. Green, W. D. Weaver and J. E. Woodwell.

The Committee on Certificates of Membership submitted a copy of the proposed certificate, and suggested that a conventional seal for the society be secured and stamped on the certificates. A motion was made that the committee be authorized to have engraved a suitable seal for the society ; also, that the design of the certificate be accepted, and that the committee be instructed to have one thousand certificates printed, and have stamped on each one the stamp of the newly-acquired seal. Motion seconded and carried. It was moved and carried that the present president and the present secretary of the society be authorized to sign the certificates as presented.

The Committee on Finance reported unpaid bills amounting to $475.47, which were approved by the Council for payment.

It was resolved that the society shall assume all expenses pertaining to the advance copies of convention papers, the convention number of the TRANSACTIONS, and the stenographic reporting of the Philadelphia Convention. The chairman of the Convention Committee stated that the unexpended balance of the convention funds will be turned over to the society.

A suggestion was offered by the chairman of the Committee on Papers that the Council authorize the appointment of a subcommittee of the General Papers Committee, whose purpose should be to take charge of the procurement of papers to be presented before the local sections, and to secure closer co-operation among the sections in the matter of preparing their programs of papers for presentation.

The Council moved to accept this recommendation and requested President Bell to appoint a committee in accordance with the same. Acting upon this motion, the president appointed the Sub-Committee of the Committee on Papers to be constituted as follows:

Mr. Preston S. Millar, Chairman.
Mr. Jos. D. Israel, Secretary, Philadelphia Section.
Mr. R. C. Ware, Secretary, New England Section.
Mr. Geo. H. Jones, Secretary, Chicago Section.

Relative to the paper on "High Efficiency Illuminants" by Mr. H. M. Daggett, Jr., it was moved and duly carried that the matter be referred to a committee of three to be appointed by President Bell—of which the President shall be one—to look into the facts of the publication of this paper, and to decide whether or not it shall be published in the TRANSACTIONS.

President Bell appointed Mr. C. O. Bond and Dr. A. E. Kennelly to serve on this committee. After having investigated the facts the committee reported that, in view of the unauthorized publication of the paper in full in a technical journal and also in the form of a bulletin by a manufacturing company, it has become unavailable for publication in the TRANSACTIONS.

The following members were elected on the dates specified:

MEMBERS ELECTED JULY 14, 1908.

AVERY, ARTHUR B., Salesman, Cleveland Gas & Electric Fixture Company, Conneaut, Ohio.

CARPENTER, HAROLD, Superintendent of Construction, Astoria Light, Heat & Power Company, Astoria, L. I.

FIELD, ERNEST L., Manager, Norfolk Construction Company, Hyde Park, Mass.

GRAHAM, ROBERT L., Salesman, Cleveland Gas & Electric Fixture Company, Conneaut, Ohio.

HOLZMAN, WILLIAM F., Consulting Engineer, 420 West Flournoy St., Chicago, Ill.

JOHNSTON, M. E., Secretary and Treasurer, Universal Engineering & Operating Company, 79 Wall St., New York.

KENNEY, FREDERICK P., Electrician, Waltham, Mass.

LEARNED, WALDO A., General Superintendent, Newton & Watertown Gas Light Company, Newton, Mass.

LYON, W. P., Estimator, Chicago Edison Co., 139 Adams St., Chicago, Ill.

MAXHEIMER, F. C., Cleveland Gas & Electric Fixture Company, Conneaut, O.

NICHOLS, WILLIAM B., Assistant General Manager, Citizens Gas Light Company, 11 Granite St., Quincy, Mass.

RILEY, J. M., Assistant General Manager, Chelsea Gas Light Company, Chelsea, Mass.

SPANGENBERG, BREWSTER H., Engineer and General Manager, Rotary Meter Company, 280 Broadway, New York.

SWANN, THEODORE, Owner and Engineer, Swann Electric Company, Bristol, Va.

TWEEDY, E. F., Manager, 2nd District Office of New York Edison Company, 124 West 42nd St., New York.

VAN SANT, FRANK R., Incandescent Lamp Salesman, Edison Lamp Works, General Electric Company, Harrison, N. J.

WHITMAN, M. GILBERT, Salesman, Cleveland Gas & Electric Fixture Company, Conneaut, Ohio.

MEMBERS ELECTED SEPTEMBER 24, 1908.

ABELL, H. C., Mechanical Engineer, 40 Wall St., New York.

ANTHONY, E. E., District Sales Manager, The Tungstolier Company, 520 Citizens Bldg., Cleveland, Ohio.

ASHE, SIDNEY WHITMORE, Consulting Electrical Engineer and Educator, 440 East Fifth St., Brooklyn, N. Y.

AUSTERMUHL, EDWARD C., 534 Bailey St., Camden, N. J.

BABCOCK, EDWIN W., Superintendent Electrical Construction, Edison Electric Illuminating Company, Brooklyn, N. Y.

BARSTOW, W. S., President, W. S. Barstow & Company, 50 Pine Street, New York.

BEEBE, T. R., Associated with Commercial Department of People's Gas Light Co., 155 Michigan Ave., Chicago, Ill.

BENEDICT, CLARENCE M., New Business Dept., United Gas Improvement Company, Philadelphia, Pa.

BERRY, S. F., Inspector, Holophane Glass Company, 233 Center Ave., Newark, Ohio.

BLOOMINGDALE, CHARLES, JR., Advertising Manager, Welsbach Company, 412 United Gas Improvement Bldg., Philadelphia, Pa.

BUNNELL, CHARLES M., Associated with Lamp Sales Dept., General Electric Company, Harrison, N. J.

BUSCHMANN, A. J., Electrical Contractor, 72 West 38th St., New York.

CADY, FRANCIS E., Assistant Physicist, Bureau of Standards, Washington, D. C.

CALLENBACH, J. A., Chemist, 131 Maple Terrace, Merchantville, N. J.

CHUBBUCK, S. E., Manager Welsbach Company, 14 North Charles St., Baltimore, Md.

CLARK, JOHN A., JR., Supt. of Distribution, Orange Dist., Public Service Corporation, East Orange, N. J.

COLQUHOUN, EDWARD M., New Business Agent, United Gas Improvement Company, N. W. Corner Broad and Arch Sts., Philadelphia, Pa.

DASHIELL, PHILIP THORNTON, Assistant Engineer, Gas Dept., Public Service Corporation, 446 Market St., Newark, N. J.

DECK, BENJ. FRANKLIN, Draughtsman, Welsbach Company, Gloucester, N. J.

ELCOCK, THOMAS R., JR., Associated with New Business Dept., United Gas Improvement Company, Philadelphia, Pa.

FARRAND, DUDLEY, 2nd Vice-President and General Manager, Public Service Corporation, 207 Market St., Newark, N. J.

FISHER, DANA L., Electrical Engineer, 220 Devonshire, Boston, Mass.

GALLOWAY, FRANK B., Sales Manager, Tungstolier Company, 520 Citizens Bldg., Cleveland, Ohio.

GARLAND, W. L., General Agent, Safety Car Heating & Lighting Company, 501 Arcade Bldg., Philadelphia, Pa.

GRAHAM, B. D., Holophane Glass Company, 259 West Church St., Newark, O.

GWILLIAM, GEORGE T., Civil Engineer, The Union League, Philadelphia, Pa.

HANCHETT, GEORGE T., Electrical and Mechanical Engineer, 237 Fulton St., New York.

HELM, O. C., 38 Lake St., Chicago, Ill.

HENRY, J. R., Salesman, Chandeliers, 265 South 4th St., Philadelphia, Pa.

HERING, CARL, Electrical Engineer, 929 Chestnut St., Philadelphia, Pa.

HILES, THERON L., Associated with Rushmore Dynamo Works, 1330 Michigan Ave., Chicago, Ill.

HOAR, F. EMERSON, Electrical and Illuminating Engineer, Metropolis Bank Bldg., San Francisco, Cal.

HOLDCRAFT, CHAS. A., Photometrician, Welsbach Company, Gloucester, N. J.

INGLER, W. A., Designer, Holophane Glass Company, 226 Hudson St., Newark, O.

INNIS, GEORGE C., Manager, New England Branch, Tungstolier Company, 25 Woolson St., Mattapan, Mass.

IVES, HERBERT E., Assistant, Bureau of Standards, Washington, D. C.

KIMBALL, EDWARD C., Office and City Sales Agent, Edison Electric Illuminating Company, Boston, Mass.

KRANTZ, H., President, H. Krantz Mfg. Co., 160 Seventh St., Brooklyn, N. Y.

LARRABEE, HAROLD D., Manager, Green Mountain Electric Company, Montpelier, Vt.

LEE, JAMES W., JR., Associated with General Electric Company, 5111 Catharine St., West Philadelphia, Pa.

MAGRUDER, CHAS. A., Illuminating Engineer, Bryn Mawr, Pa.

MAIZE, FRANK E., Assistant Manager, Electrical Bureau, 618 City Hall, Philadelphia, Pa.

MALONEY, ANDREW P., Manager, Treasurer and President of Gas and Electric Light Company, 1530 Land Title Bldg., Philadelphia, Pa.

MCLAUGHLIN, J. F., Chief, Electric Bureau, 626 City Hall, Philadelphia, Pa.

MIDDLEKAUFF, GEORGE W., Assistant Physicist, Bureau of Standards, Washington, D. C.

MOORE, LEWIS B., 500 Third National Bank Bldg., St. Louis, Mo.

MOSES, HERBERT W., Special Agent, Edison Electric Illuminating Company, 39 Boylston St., Boston, Mass.

MYERS, JOSEPH B., New Business Agent, United Gas Improvement Company, N. W. Cor. Broad and Arch Sts., Philadelphia, Pa.

O'CONNELL, CHARLES M., Salesman, United Gas Improvement Company, Philadelphia, Pa.

OZANIAN, JOHN, Manufacturer of Gas Fixtures, 1931 North Hope St., Philadelphia, Pa.

PARKER, HECKERT L., District Sales Manager, The Tungstolier Company, Minneapolis, Minn.

PEASE, WARD T., Salesman, Welsbach Company, 1115 Euclid Ave., Cleveland, O.

POSS, F. H., Manager, San Francisco Branch, Holophane Company, 656 Howard St., San Francisco, Cal.

RAINSBURG, CHARLES J., Assistant to Engineer of Philadelphia Gas Works, 24 North 22nd St., Philadelphia, Pa.

REIGER, E. C., Holophane Glass Company, 15 East 32nd St., New York.

RICE, LAWRENCE W., Salesman, 1037 East Chelten Ave., Germantown, Philadelphia, Pa.

ROGERS, G. WHITNER, Associated with Welsbach Company, Philadelphia, Pa.

ROWE, EDWARD B., Illuminating Engineer, Holophane Company, 227 Fulton St., New York.

SAUNDERS, WILLIAM E., Engineer, Torresdale, Philadelphia, Pa.

SEINJO, YOSHIO, Engineer, Tokyo Electric Company, 269 Shirokane, Sanko-cho, Shibaku, Tokyo, Japan.

SIMONS, EDWARD L., Electrician, Lansdowne, Pa.

SOLOMON, NATHAN CLARENCE, Electrical Engineer, Associated with George H. Shuman, 13 East 30th St., New York.

STEBBINS, E. B., 3615 Baring St., Philadelphia, Pa.

STEVENS, J. FRANKLIN, President, Keystone Electrical Instrument Company, 9th St. and Montgomery Ave., Philadelphia, Pa.

STILES, T. WILSON, Tungsten Expert, 301 West Main St., Moorestown, N. J.

THORN, FRED G., JR., Civil Engineer and Chief Draughtsman, United Gas Improvement Company, 24 North 22nd St., Philadelphia, Pa.

TOMPKINS, WILLIAM M., Electrician, 713 Pembroke Ave., East Lansdowne, Pa.

TORCHIO, PHILIP, New York Edison Company, 57 Duane St., New York.

TURNER, EUGENE M., Publicity Department, Welsbach Company, Gloucester, N. J.

TYSON, J. C., Manager, Savannah Elec. Repair Company, Savannah, Ga.

WEIDERMAN, GEORGE, President, George Weiderman Electric Company, Inc., 191 Flatbush Ave., Brooklyn, N. Y.

WOOD, C. D., JR., Electric Home Supply Company, 45 West 34th St., New York.

MEMBERS ELECTED OCTOBER 5, 1908.

ALLISON, WALTER A., Gas Engineer, United Gas Improvement Company, Philadelphia, Pa.

GIBBS, LOUIS D., Special Agent of Publicity, Edison Electric Illuminating Company, 39 Boylston St., Boston, Mass.

KRUGER, JOHN L., Electrical Contractor, 137 Grand Ave., Brooklyn, N.Y.

MAXWELL, ALEXANDER, General Foreman, Test Dept., New York Edison Company, New York.

O'LEARY, J. J., President, Buffalo Electrical Contracting Company, 62 Niagara St., Buffalo, N. Y.

PLOWMAN, J. E., Illuminating Engineer, 1102 American Bank Bldg., Seattle, Wash.

SPAULDING, RUSSELL, 346 Broadway, New York.

THOMSON, GEORGE W., New Business Manager, Chester, Pa.

WILLIAMSON, G. E., Illuminating Engineer, Denver, Col.

CHICAGO SECTION.

At a meeting of the Chicago Section of the Society, on October 15, a paper was presented by Messrs. A. D. Curtis and A. J. Morgan, entitled "Indirect Lighting." The meeting was held at the residence of Mr. Curtis, where the system of lighting described in the paper was shown in actual service. The paper and the discussion following its presentation will be published in a subsequent issue of the TRANSACTIONS.

NEW YORK SECTION.

A meeting of the New York Section was held on October 15, when a committee consisting of Dr. A. H. Elliott, Mr. E. F. Tweedy and Mr. Norman Macbeth reviewed the papers and discussions presented at the Philadelphia Convention of the Society. The integrating sphere and the colorimeter described in two of the papers were exhibited and explained. Secretary Millar announced that definite arrangements have been made for three monthly meetings of the Section. The library, the illumination of which was described in the Convention paper of Mr. L. B. Marks, will be visited during November, when the author will explain the lighting features. Dr. C. P. Steinmetz will deliver a lecture during December on a subject not yet announced. The subject of street lighting will be discussed at the January meeting, when papers will be read by Mr. W. C. Allen and Mr. C. S. Rhodes.

NEW ENGLAND SECTION.

The New England Section held a meeting on October 23 for reviewing and discussing the Convention papers, copies of all of which were distributed. The papers were abstracted by members who had attended the Convention, including Dr. Louis Bell, Mr. Louis D. Gibbs, and Mr. J. S. Codman, after which a general discussion was had. There were 27 members in attendance.

ANNUAL CONVENTION NOTES.

The Second Annual Convention of the Illuminating Engineering Society, which was held in Philadelphia on Monday and Tuesday, October 5 and 6, proved successful beyond all expectations. The total registered attendance reached 400, of whom 242 were members, and 158 guests.

The address of welcome to the city was delivered by Mr. William F. Gleason, as secretary to Mayor Reyburn who was prevented from being present on account of his duties in connection with the exercises of Founders' Week. After this address, the Chairman of the Committee on Arrangements, Mr. George Ross Green, introduced Dr. Louis Bell, who delivered his Presidential Address, entitled, "Street Lighting." The next item on the program, and the last for the opening session on Monday morning, was the reading of the "Report of the Committee on Nomenclature and Standards," by Dr. E. P. Hyde, secretary of the subcommittee, in the absence of the chairman, Dr. A. C. Humphries.

The present issue of the TRANSACTIONS contains all of the Convention papers for which corrected reports of the discussions were returned by the speakers during October. It is hoped that the discussions of the remaining papers will be revised by the speakers in time for appearance in the November issue.

Additional sessions for the presentation and discussion of papers were held on Monday evening, Tuesday morning, and Tuesday afternoon. At the opening of the session on Monday evening, the President announced that certificates of membership in the Society are now available. The certificates are properly engraved and will furnish a pleasant remembrance of membership in the Society. Application should be made to the secretary, the price being one dollar per certificate.

On Monday afternoon the members and guests viewed the

military parade of regular and state troops, after luncheon had been served at Hotel Walton. On Tuesday evening a special vaudeville entertainment was provided at the Walton. An excellent exhibit of devices and apparatus of interest to illuminating engineers, including the integrating sphere, the colorimeter, and gas lighting conveniences, described in three of the Convention papers, was held in a special room at the Walton devoted to this purpose.

GENERAL COMMITTEES.

General Convention Committee.

Mr. George Ross Green, Chairman

Mr. C. O. Bond	Mr. Geo. H. Jones
Mr. J. S. Codman	Mr. V. R. Lansingh
Mr. J. R. Cravath	Mr. P. S. Millar
Mr. W. W. Freeman	Mr. R. J. Rolston
Mr. G. R. Hemminger	Mr. R. C. Ware
Mr. Jos. D. Israel	Mr. W. D. Weaver.

Sub-Committee on Arrangements.

Mr. George Ross Green, Chairman

Mr. C. O. Bond	Mr. Jos. D. Israel
Mr. G. R. Hemminger	Mr. R. J. Rolston.

Papers Committee.

Mr. W. D. Weaver, Chairman

Mr. C. O. Bond	Dr. E. P. Hyde.
Mr. J. R. Cravath	

LOCAL COMMITTEES.

Finance Committee.

Mr. J. T. Maxwell, Chairman — Mr. W. H. Gartley.

Committee on Publicity.

Mr. C. W. Hare, Chairman

Mr. Chas. Bloomingdale — Mr. H. K. Mohr.

Committee on Hotels.

Mr. C. R. Hemminger, Chairman — Mr. J. D. Israel.

Railroad and Transportation Committee.

Mr. A. H. Manwaring, Chairman — Mr. H. W. Davies.

Committee on Exhibits.

Mr. J. B. Klumpp, Chairman

Mr. P. H. Bartlett	Mr. Preston S. Millar
Mr. L. S. Baxter	Mr. Emile G. Perrot
Mr. Washington Devereaux	Mr. G. L. Thompson
Mr. Garrett F. Hom	Mr. M. C. Whitaker.

COMMITTEE ON PAPERS.

Mr. C. O. Bond, Chairman   Mr. C. J. Russell.

RECEPTION AND ENTERTAINMENT COMMITTEE.

Mr. R. J. Rolston, Chairman

Mr. P. H. Bartlett
Mr. Chas. Bloomingdale
Mr. C. O. Bond
Mr. Thomas Burke
Mr. Horace W. Castor
Mr. F. G. Corbus
Mr. L. J. Costa
Mr. Robert E. Dallas
Mr. Hubert W. Davies
Mr. Washington Devereaux
Mr. F. E. Dolbier
Mr. W. F. Douthirt
Mr. Lewis P. Dutton
Mr. W. C. L. Eglin
Mr. Walton Forstall
Mr. I. H. Francis, Jr.
Mr. W. H. Gartley
Mr. A. R. Granger
Mr. Geo. Ross Green
Mr. C. W. Hare
Mr. G. R. Hemminger
Mr. G. F. Hom
Mr. J. D. Israel
Mr. W. H. Johnson
Mr. G. H. Hoffman
Mr. J. B. Klumpp
Mr. H. A. Koockogey
Mr. T. J. Litle
Mr. W. J. Lochart
Mr. R. B. MacCreery
Mr. W. J. Manning
Mr. A. H. Manwaring
Mr. J. T. Maxwell
Mr. John Meyer
Mr. H. K. Mohr
Mr. F. N. Morton
Mr. G. B. Muth
Mr. Clayton W. Pike
Mr. G. Bertram Regar
Mr. H. H. Richman
Mr. C. J. Russell
Mr. S. W. Smith
Mr. Samuel Snyder
Mr. Paul Spencer
Mr. G. L. Thomson
Mr. C. W. Wardell.

TREASURER OF CONVENTION.

Mr. J. T. Maxwell.

SECRETARY OF CONVENTION.

Mr. J. D. Israel.

STREET LIGHTING.[1]

BY DR. LOUIS BELL.

I need hardly say that it gives me great pleasure to meet the society at this second Annual Convention. But is is not for the purpose of obvious congratulations in the gathering that I arise now, but rather for the purpose, if I may put it so boldly, of bringing before you reasons for repeating the cry of Ajax for "more light."

Unfortunately, we, in these times, can only call for more light—we have not the privilege of Joshua in holding the sun and the moon still to provide it for us. Things were done in a better way in the olden times, they have always said.

The topic which I wish to bring before the Convention definitely, then, is the topic of street lighting,—some of the things which underlie it, some of the things which are needed to make it sound in practice as well as in theory.

Man is becoming more and more a nocturnal animal. It was not more than two hundred odd years ago, perhaps about the time that Philadelphia was founded or a little later, that the first attempts at systematic street lighting were made. One has but to consult the evidences of old books and old prints to see very plainly that our ancestors and contemporaries of the founders of Philadelphia had very little to show in the way of public lighting. A candle flickering in the wind near a window, a horn lantern casting a feeble glimmer down the street and dribbling oil on the passers-by, and a pine knot or a flambeau of asphaltum, borne by a torch-bearer hurrying through the crowd, and thrusting his smoky weapon in the face of the passers-by—these were about all that the world could boast of in the way of street lighting two hundred or two hundred and fifty years ago.

The activities of men are so far transferred from day to night, at the present time, that it becomes absolutely necessary to make provision for those who are traveling about after night-fall, and for the general business that is carried on at night,—business of

[1] Presidential address at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

the theatres and concerts, and business of people hurrying from one place to another in the ordinary routine of their day's work extending until after sunset. For all of these purposes light, and plenty of it, is necessary, but this light we have only to a rather limited extent in most cities.

The fundamental criticism against most attempts at street lighting lies, not in the illuminants used, nor in their application, so much as in an improper adjustment of the illumination to the needs of the city. Street lighting has been a growth and an evolution, but like all growths, it has proceeded to a certain extent along the lines of least resistance.

The result is, that looking over a city,—particularly an American city, however good the intention of the city government, however excellent the technical skill of those who furnish the light, much is still left to be desired. The difficulty lies in the fact that the illumination is spread out too thin, so to speak. We do not carefully discriminate between streets the nature of the usage of which demands considerable light, and those streets which are perfectly well illuminated with a much less quantity of light. We attempt to follow out the general American theory that all men and all things are free and equal, and distribute a very finite amount of light over a very large area, with some approximation to uniformity, lest we hurt the feelings of our good fellow citizens by insinuating that Z Street does not carry the heavy traffic, and is not so crowded with by-passers in the evening as A Street. In point of fact, we all know in going through a city, that there are certain great avenues of evening traffic, certain places where light is needed all night, and every night, and a great deal of it. The commonest failure is the failure to recognize this simple fact, and in attempting a certain degree of uniformity, never exact uniformity, of course, which is quite improper when one considers the use to which the various streets are put.

There should be what there generally is not,—a very careful adjustment of the resources of the city in the matter of public lighting, so as to facilitate the greatest possible amount of the evening traffic. This means that in streets which are largely used during the evening, illumination commensurate with their importance should be used, but for streets where the night traf-

fic is light, and where passers-by are few, only light enough is needed to enable the people to get about comfortably. There is still a third class of street which needs individual treatment, sometimes gets it and sometimes does not, and that is the outlying street,—the merely suburban road,—the country road which still comes within the province of the municipality to illuminate. In places of that sort funds are seldom available for providing anything like serious illumination, but a great deal for the convenience of the public can be done.

The purpose, the fundamental purpose of lamps in these outlying, little-used streets, which yet need some light, is merely to serve as markers of the way; in other words, in these unfrequented places, streets where illumination of the first order is unnecessary, and that of the second order needlessly great, the important thing is so to distribute the light that the illuminants serve to mark the way and clear the passage for the passers-by. In such places the somewhat common practice of using very large units of whatever kind is obviously improper. One marker a mile of 1,000 candle-power is not anywhere nearly so good as half the amount of light put out at short distances in smaller units; in other words, where a lamp is used merely as a marker to show the way, and a general illumination can not be undertaken, the best thing is to employ small units and locate them so as to get the best results obtainable from the energy in whatever way it may be applied.

There are then three distinct classes of streets which must be considered in the problem of the theoretical character and practically useful illumination. First there are the chief streets,—the heavy arteries of traffic which need all the light they can get. Then there are the secondary street, making up the bulk of an ordinary city, which need to be well lighted but do not require a blaze of illumination, because they are used in an entirely different way from the main streets. And finally there are the tertiary streets, in which the lighting is intended merely to show the way.

In our ordinary practice here these classes run into each other by such gradual transitions that one can hardly tell whether there was any fundamental idea in the minds of the persons who laid out the streets or not. Our chief streets, as a rule, all over

the country, are really poorly lighted, the secondary streets not particularly well lighted—sometimes a little better than they should be, and sometimes not quite so well—and the tertiary streets frequently rejoice only in one illuminant every long block, useless for practical purposes except within a very short radius, and utterly failing, too, in the proper marking out of the way. As regards the absolute amount of light required there will be always difference of opinion. In the principal streets, where the traffic is constantly heavy, I think that one would not go far wrong in following the principle that one should have light enough to see to read a paper by. I would not recommend the citizens to sit out on the curb and read their evening papers, but I think the chief streets of the city should be always so well lighted that if any one must consult a note-book to find his way, or wants to refer to a letter for any purpose, he should be able to read it without having to walk a half block to get under the nearest lamp. As to the secondary streets, much less amount of light than that is desirable, and not so much is necessary, in fact. The tertiary streets can use a still less amount.

In connection with this matter it is noteworthy that the foreign practice in England and on the continent is to provide in the different streets light enough to read a paper by. This summer I traveled miles through the chief streets of the European cities, and was able to read the fine print of a Baedecker every foot of the way by the light of the street lamps alone. That is the ordinary standard of goodness which is lived up to in the large foreign centers.

In actual amount the London canon in lighting calls for an average of something like a quarter of a foot-candle, as against one-tenth, or one-twentieth in the ordinary American city. The secondary streets on the side use about the same value of illumination as the ordinary street here. The tertiary streets are still less lighted, perhaps half as much, but the light is invariably secured by comparatively small units, either gas or electric, instead of putting up very big units. So much for the general design of the illumination.

Now as to its manner. In the first place, whatever the intensity adopted, it is desirable to have a fairly uniform distribution. By that is not meant uniformity at the expense of low maxima,

but it is undesirable so to scatter the lamps as to have a great deal of light here and there and none between. Secondly, it is desirable to diffuse the light so as to make it as useful as possible. One of the great points of difference between the practice here and European practice in that diffusing globes are practically in universal use except in the United States; and therefore there is less uniform lighting here than almost any where else. Merely, if for no other reason, because the light is not diffused, the illuminants themselves are of a different character, are intensely brilliant, and the result is a certain dazzling effect which very much decreases the practical usefulness of the light, on just the same principle that a bare lamp in front of one's eyes is a very inconvenient thing.

In the matter of distribution one cannot sacrifice too much for the sake of uniformity. It is a fact which one will find out readily by observation that one can light a street uniformly and yet badly. There can be a fairly good minimum on a street, and yet it may be lighted badly for the purposes of a chief street. It may be well to mention two places that I have visited. One is a place in Paris where there is a tremendous concentration of illuminants. All of the units are small and massed together, massed in a way that would show, if one deliberately sat down and figured the illumination, a result which would cause one to feel proud of it. Practically, however, the place is badly lighted. There is no effect of brilliancy; one can see fairly well all about, but the place is nevertheless insufficiently lighted.

I call to mind another place in Berlin where the average intensity is probably not very much higher,—not more than fifty per cent., perhaps, where the units used are of the same kind, but of very much greater intensity. The effect is beautiful. In other words, one can dwell neither on the minimum in the street as a canon of good lighting, nor on the average as seen along the street. One must bear in mind that a big centre of light, throwing an immense amount of light out into the street and being reflected from the house, adds a great deal to the efficient illumination of a street for the purpose for which street illumination is desired. One can get fairly uniform lighting, and he can take the same amount of power and get less uniform lighting which will be quite as effective. In other words, one

must look at the thing as a practical matter, and not as a mere theoretical matter of so many hundredths of a foot-candle. It does not take an expert in illumination to see whether a street is badly lighted or not, and it does not, consequently, take an illuminometer, with measurement in the thousandths of foot-candles at the half-way distance between the lamps, to show that improvements are necessary. The thing is a strictly practical matter, and should be treated as such.

That brings up the question of the direction of measurement, —how shall we measure the light on the street? The customary measurement in this country is a tacit apology for bad lighting. The customary method of measuring here is a measurement practically halfway between the lamps with the photometer disc, or other measuring instrument held normal to the ray. If one gauges his illumination solely by such readings as this, he can be guaranteed of a badly lighted street in every case, because the tendency of competition, from whatever source it comes is to secure that minimum at as low a maximum as possible, modifying the illuminants to be as useless as possible, subject to the condition of getting the low minimum, and the result is a badly lighted street. I could mention types of illuminants which have been deliberately specialized for the purpose of giving two-hundredths or three-hundredths of a foot-candle, at some point down the street, whereas if the same illuminant were designed, not to give a special form of illumination, but to give the best efficiency of which it was capable, it would not only be possible to make it light the distant parts of the street, but the whole of the street; in other words, there are cases in which the efficiency is deliberately sacrificed for the sake of what is nothing more or less than bad distribution.

Every effort toward economy should be an effort directed to increase the total flux of light, because with our modern illuminants this is chiefly to be taken into consideration for street lighting.

There is no excuse to-day, whatever there may have been ten years ago, for specializing distributions by means of the design of the illuminant, because, at the present time, it must be shielded. One can both distribute and diffuse light at the same

time, and what is more important, when a street is lighted on any adequate scale all spherical distribution obtainable is needed.

The foreign practice in the matter of direction of measurement is to measure the illumination as it falls on a plane four feet above the ground, measuring on the horizontal, and thus measuring the resolved component. One-tenth of a foot-candle so measured very obviously means a great deal more than the tenth which is obtained on the normal measurement. One is sometimes tempted to wonder on what basis this particular measurement on the horizontal was chosen and why the thing has not been more fully discussed. It has not been more fully discussed here because people do not like to talk about that little resolved component. It is so much nicer to talk about the larger normal. It is not discussed abroad with any great vigor, simply because in the first place the light is sufficient to give a thoroughly adequate measurement on the horizontal, and, second, because, as a matter of fact,—it happens to be a rather curious one, too,—the lamps in England and on the Continent are customarily placed at just about the point that makes it a matter of indifference to them which way they are photometered. That is to say, in measuring the illumination on the horizontal plane one measures the effect from two lamps. In measuring on the normal the effect from only one is obtained. Now, at the distance and height at which big units are customarily placed abroad, whether gas or electric, only four or five times the height of the post being taken as the distance between lamps, the double projected illumination of adjacent lamps becomes substantially identical with the normal illumination of each, so that it ceases to be a vital question abroad whether one or the other method is used, the two being nearly coincident. The thing which I wish to point out is, that if the illumination on the normal is the criterion, for heavens' sake give enough of it to see something by, and not the apologetic two-hundredths or three-hundredths of a foot-candle which has been too often talked about.

This brings up the question of economy in street-lighting, and in particular I want to devote a brief moment of animadversion to the so-called moonlight schedule. I think this curious minimum of a couple of hundredths of a foot-candle which has been followed too long came largely from the fact that that value

was supposed to be about the maximum intensity of moonlight in this latitude. One can read by a full moon, which gives one-hundredths to two-hundredths of a foot-candle. However, moonlight is diffused, diffused with a vengeance, and from my observation I should say that moonlight, on account of its diffusion, is at least two or three times as good as an equal fraction of a foot-candle delivered from an arc lamp, or Welsbach, or large incandescent lamp, or what not, merely because in the moonlight there is complete diffusion and low intrinsic brilliancy which allows the eye to do its best work. One does not experience trouble in driving an automobile in moonlight if he has a good head-lamp; he might have trouble in driving an automobile even with a good head-lamp in a lighted street, because the lamps in the street flash straight in his face. The practical value of diffusion is recognized at once when it is called to our attention, and it should be recognized in street lighting.

The moonlight schedule, which is the favorite method of economizing, is most deceptive. In the first place, ordinary moonlight in this latitude is less than two-hundredths of a foot-candle. In the next place, the half moon intensity, instead of being half as good as a full moon, is only about one-tenth as good. That means that there is a large element of specular reflection in moonlight, the same as from a piece of polished cardboard. Consequently the two-hundredths of a foot-candle in three or four days sinks to an insignificant figure; there is only one week in the month when the moonlight is of a magnitude to be of any particular account.

Customarily the moonlight schedule is perhaps two-thirds of the full all night and every night schedule, while if proper illumination is to be obtained, it should be three-fourths, or eight-tenths, or something of that order.

A second common effort at economy is through the means of half-night lighting. Half-night lighting from the standpoint of the needs of the public is a great deal better than the moon-night schedule, because so far as the brilliantly lighted streets of the city are concerned, the legitimate activities of the city cease before morning, so that there is some reason in reducing the number of lamps after mid-night or one o'clock. If anybody has to economize rigidly, it is far better to disconnect every other

lamp, or something of that kind, than it is to run them on a regularly reduced moonlight schedule.

It is never desirable to go into half-night lighting or petty economies of that kind anyhow, and my purpose here is to point out particularly that the moon is a bad thing to depend upon. If the illumination must be decreased at certain times from motives of economy, it is better to do so at convenient times and systematically than to depend on moonlight and weather conditions.

Now as to important things of the future in street lighting. The first of them is a recognition of the fact that streets are lighted for people to use; that the streets should be lighted with reference to the use which is going to be made of them, and on the whole they should be much more brilliantly lighted than is customary in this country to-day. More light is needed not only for the general purposes of the city, but for police purposes. The latter all-night lighting is a very important matter. It is an old saw among electric men that an arc lamp is as good as a policeman. That may or may not be true in the exact ratio, but it is certain that a well lighted city, a city lighted well all over, is a safer city at night than the average poorly lighted city.

The next question which arises is by what means shall lighting be done? We are now in the transition period. As every engineer connected with the gas and electric light industry knows, the one thing which is perfectly safe to say, about which there can be very little doubt, is that the old illuminants, the old types of street lamps, both gas and electric, must go, and go very rapidly. The old time, glimmering arc lamps, the faded out and worn out vertical Welsbach, both must go to the general scrap heap of oblivion,—this they must do before a very long while, and in their place there will be an entire different order of lamps, which, by increasing the efficiency, will enable the streets to be lighted as they ought to be, about as cheaply as they are lighted now. We have come to a parting of the ways. We must turn away from our old idols and bend ourselves toward the new ones; we must call on Efficiency, the tutelary divinity of engineers whose worship has been too long neglected. Three or four years will work a change. The handwriting is

on the wall plainly enough now for anyone who cares to read it, and we are going to have, and we must have, and we ought, as illuminating engineers, to insist on having, the kind of public lighting which has never been seen in this country except in one or two isolated spots. We need more light, better diffused and better distributed, and it is up to us, if we are to make any claims to be pioneers in the way of illuminating engineering, to keep at this subject technically and personally until we get the more light which we ought to have.

REPORT OF COMMITTEE ON NOMENCLATURE AND STANDARDS.[1]

BY DR. A. C. HUMPHREYS.

Your Committee on Nomenclature and Standards, while not ready to make a final report, deems it advisable to report the progress already made in the direction of establishing a common national and international unit of candle-power. The work of your committee has so far been chiefly concentrated on this most important feature of its assignment of duties.

The special work referred to was assigned to a sub-committee, and the report of this sub-committee, through its secretary, Dr. E. P. Hyde, will best serve to indicate the progress already made.

Your committee trusts that the work so far accomplished will be approved by the society.

Following is the report of Dr. E. P. Hyde, secretary of the sub-committee :

REPORT OF SUB-COMMITTEE ON NOMENCLATURE AND STANDARDS OF THE ILLUMINATING ENGINEERING SOCIETY

At the first annual convention of the Illuminating Engineering Society held in Boston, July 30-31, 1907, the question of a possible agreement upon a common national and international unit of candle-power was presented[2] for consideration. As a result of the interest in this subject manifested by the members of the society in the discussion which followed the reading of the paper, the question was further presented for consideration at a meeting of the American members of the Committee on Nomenclature and Standards, which was held in Boston July 30, 1907, during the convention. At this meeting the following resolution was unanimously adopted :

Resolved : — "That a sub-committee on nomenclature and Standards be appointed by the Chairman to confer with similar committees of the American Institute of Electrical Engineers

[1] A report submitted at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

[2] Primary, Secondary and Working Standards of Light ; *Transactions* Illuminating Engineering Society, Vol. 2, No. 7, pp. 426-439 ; October 1907.

and the American Gas Institute, with a view to the consideration of the adoption of a unit of light, and with the request that it report to the main committee at the earliest possible date."

In accordance with this resolution the Chairman appointed the following as members of the sub-committee on Nomenclature and Standards: Dr. Louis Bell, Mr. J. B. Klumpp, Dr. C. H. Sharp, and Dr. E. P. Hyde. The sub committee held a meeting in New York on September 20th, at which Dr. Bell and Dr. Hyde were elected chairman and secretary, respectively, and plans were made for interesting the American Institute of Electrical Engineers and the American Gas Institute in the movement for a common national and international unit of candle-power. To this end the following communication was drawn up and presented to the American Gas Institute at its annual convention held at Washington October 16-18, 1907.

WALTON CLARK, *President.*

DEAR SIR: About one year ago, the Illuminating Engineering Society created a committee, representing the varied interests in this country and abroad, to consider the question of establishing suitable, and, if possible, universal nomenclature and standards for the science of illuminating engineering.

The question of a common national and international unit of candle-power was taken into consideration by the American members of this International Committee, and upon motion, Dr. A. C. Humphreys, the chairman of this committee, appointed a sub-committee to confer with similar committees from the American Gas Institute and the American Institute of Electrical Engineers.

As a result of numerous recent investigations it has been established that the value of the candle unit defined as 1/10 of the intensity of the Harcourt 10-cp. pentane lamp is different from that obtained through the Hefner, by the use of the ratio, one Hefner candle = 0.88 British Parliamentary candle. The amount of the difference is not definitely known, but is probably about 4 per cent., the unit obtained through the Harcourt 10-cp. pentane lamp being smaller. Whether this difference is due to a change in the value of either of the two units (the candle unit in England or the Hefner unit in Germany), or whether it is due to errors in the earlier comparisons between the two units which gave the ratio 0.88 is immaterial for our present purpose. The important fact which we desire to present for your consideration is that although in the photometry of both gas and electric lamps in the United States the unit has nominally been the British Parliamentary candle, it has been obtained in different ways in the two industries.

In the photometry of gas the English example has been followed, and the candle unit in use in this country is probably not

very different from that in use in England. On the other hand, the unit used in the photometry of electric lamps, following the recommendation of the American Institute of Electrical Engineers, has been obtained through the Hefner by the use of the ratio, one Hefner candle = 0.88 British Parliamentary candle. We are, therefore, confronted at present with the existence of two different units of candle-power in the United States, differing from each other by about 4 per cent. It is evident that such a condition in not only unfortunate but extremely disadvantageous to the better interests of either industry, and any action that would tend to bring the two units into agreement should be welcomed by all concerned, provided such action does not work hardship upon any of the interests involved.

With the establishment of State commissions for gas and electricity, which will look more and more to the Federal Bureau of Standards for standards of candle-power, complications will certainly result if the unit recognized in any industry is not in agreement with that maintained at the Bureau of Standards; and it is obviously impossible for the Federal government to maintain and legalize two different units for use in the photometry of gas and electric lamps. In a recent paper published by the National Bureau of Standards at Washington, attention was called to the discrepancy between the candle unit obtained through the Harcourt 10-cp. pentane lamp and that obtained from the Hefner by the use of the ratio 0.88.

In this same paper attention was also directed to the question of possible international action looking toward the establishment of a common unit of candle-power for England, France and the United States. The units in use in these three countries are so nearly alike that, with the accuracy at present obtainable in industrial photometry, no serious results would follow a compromise by which all three countries would agree upon a common unit of candle-power. If the value of this common unit were taken as the average of the values of the units maintained at the national laboratories in the three countries, it would be very close to the mean between the two units in use in the United States in the photometry of gas and electric lamps. Therefore, a compromise in the interest of international unity would require no greater changes of unit than a compromise in the interest of national unity. Moreover, the change in unit would in no case be greater than about two per cent., and the effect of such a change would not be seriously felt, even in the photometry of incandescent lamps where the highest accuracy in commercial testing is attainable.

Since the German unit of candle-power differs by 10 or 15 per cent. from the average value of the units in England, France and the United States, it would not seem desirable to in-

clude the German unit in taking the mean value. Either Germany could elect to adopt the international candle unit, or else the ratio of the Hefner candle to the international unit could be determined.

In consideration of the facts stated above, we, the undersigned, in behalf of the Sub-Committee of the Committee on Nomenclature and Standards of the Illuminating Engineering Society respectfully request, therefore, that the American Gas Institute appoint a committee to confer with the sub-committee of the Illuminating Engineering Society on the question of the possible adoption of a common national and international unit of candle-power.

A similar request is being made to the American Institute of Electrical Engineers, and it is hoped, through the co-operation of these two representative bodies, that some definite action will be taken.

Yours respectfully,

(Signed) EDW. P. HYDE,
J. B. KLUMPP.

This communication was referred to the Technical Committee of the Gas Institute for action, with the result that subsequently the following members were appointed to form a sub-committee of the Institute to confer with similar committees of the American Institute of Electrical Engineers and the Illuminating Engineering Society: Mr. W. H. Gartley, Mr. A. E. Forstall, Dr. A. H. Elliott and Mr. C. O. Bond.

In a similar way an invitation to the American Institute of Electrical Engineers to appoint a sub-committee to unite in conference with sub-committees of the other two bodies to consider the question of the adoption of a common national and international unit of candle-power was presented to the Standardization Committee, at its meeting in New York Nov. 7, 1907. The invitation was received favorably by the Standardization Committee, and the following sub-committee was appointed: Dr. A. E. Kennelly, Dr. Samuel Sheldon, Dr. C. P. Steinmetz, and Dr. S. W. Stratton.

The two sub-committees of the American Institute of Electrical Engineers and American Gas Institute held separate preliminary meetings and passed resolutions expressing the attitudes of the respective sub-committees on the question of the adoption of a common unit of luminous intensity. In addition to the formal committee meetings, several informal joint

conferences of representatives of gas and electric lighting interests were held, as the result of which a more thorough understanding of the present situation and of the necessity and probable effects of an agreement upon a common unit of candle-power was reached.

Finally on February 14, 1908, in the Engineering Societies Building in New York the three sub-committees representing the American Institute of Electrical Engineers, the American Gas Institute, and the Illuminating Engineering Society, met in joint conference, and organized themselves into a joint committee with Dr. S. W. Stratton, permanent chairman, and Mr. C. O. Bond, permanent secretary. In the absence of Dr. Stratton, Dr. E. P. Hyde was elected chairman pro tem of the meeting. After a lively discussion the following preamble and resolutions were unanimously adopted:

"The joint Committee composed of sub-committees of the American Institute of Electrical Engineers, the American Gas Institute, and the Illuminating Engineering Society, recognizes that although the differences among the units of candle-power in use in the United States at the present time are not greater than a few per cent., nevertheless in view of the increasing accuracy that is being demanded in industrial photometry, there is a growing need of a common unit of candle-power which shall be established and maintained at the United States Bureau of Standards at Washington, D. C., and in terms of which secondary and working standards for use in the photometry of all kinds of illuminants can be measured. The Committee further realizes the importance and desirability of international agreement upon a common international unit of luminous intensity to be used throughout the civilized world. It so happens that the common unit which would be adopted in the United States as a compromise between the candle units used in the photometry of gas and electric lamps would approximate very closely to the mean value of the candle units maintained at the national laboratories of the United States, England and France. The unit of light maintained at the national laboratory in Germany (the Hefner) differs from the candle units maintained at the national laboratories of the other three countries by so great an amount that no benefit would accrue either to Germany or to the other countries by including the Hefner in taking the mean of the various units:

And Whereas the three sub-committees in joint conference deem that the above statements embody the concensus of opinion of said committees: therefore, be it—

Resolved: (1). That the joint committee, composed of sub-committees of the American Institute of Electrical Engineers, the American Gas Institute, and the Illuminating Engineering Society, approves the adoption of a common national candle unit which shall be maintained at the United States Bureau of Standards, and in terms of which secondary and working standards for use in the various industries can be standardized, and recommends to each of the three societies here represented through the respective sub-committees the adoption of such a plan.

Resolved: (2). That this committee will support the Bureau of Standards in any action which it may take to bring about international agreement upon a common candle unit, and will recommend to each of the three societies here represented the endorsement of such action, provided the unit agreed upon shall represent approximately the average value of the candle units maintained at present at the national laboratories of the United States, England and France, or, specifically that it shall be lower than the unit at present maintained at the Bureau of Standards at Washington, D. C., by an amount not less than one (1) per cent., nor more than three (3) per cent., the exact value to be agreed upon as the result of an international conference.

Resolved: (3). That inasmuch as the adoption at this time of a definite value for the common national candle unit for the United States would embarrass the Bureau of Standards in bringing about international action, this Committee refrains at this time from recommending the adoption of a definite value for the common national candle unit, but recommends, in the interest of the various industries involved, that during the interval required for the consummation of international action a common candle unit be used which shall be two (2) per cent. less than that now maintained at the Bureau of Standards, since there can be no doubt but that such a candle unit would differ by less than one (1) per cent. from the proposed international candle; and further resolved that the Secretary of this joint committee is instructed, after the concurrence of the three societies here represented, to address a letter to the Director of the Bureau of Standards enclosing a copy of those resolutions, and requesting that the Bureau of Standards, which has taken the initiative in the present movement toward a common national and international candle unit, maintain as its working candle from this time on until definite international action shall have been taken, a candle unit two (2) per cent. lower than that which it is maintaining at the present time.

Resolved: (4). That this Committee recommends that each society here represented, acting through its own proper channels, shall address to such similar foreign societies as may be interested a statement of the movement in the United States toward

a common international candle unit, (enclosing a copy of these resolutions), and shall request the co-operation of the said foreign societies in advancing the movement."

In pursuance of these resolutions the sub-committee of the American Institute of Electrical Engineers reported the action of the joint Committee to the Board of Directors of the Institute for approval. The action of the sub-committee was endorsed, and the latter was authorized to notify the Secretary of the joint Committee to that effect, in accordance with Resolution 3.

In the Illuminating Engineering Society the resolutions of the joint Committee were endorsed by the Committee on Nomenclature and Standards, and referred by this committee to the Council of the Society. At a meeting of the Council, held June 12, 1908, the action of the sub-committee was approved. Since authority in such matters is vested in the Council of the Illuminating Engineering Society and in the Board of Directors of the American Institute of Electrical Engineers, the final action by these two bodies has already been obtained.

Before the resolutions of the joint Committee can be approved finally by the American Gas Institute they must be presented to the society for action, at its annual convention, which is to be held in New York in October. It is encouraging to report, however, that the resolutions of the joint committee have already been endorsed, both by the Technical Committee and subsequently, on March 17th, by the Board of Directors of the Institute. Should the Institute at its convention act favorably on the resolutions of the joint Committee, the Secretary of this committee will address a letter to the Director of the Bureau of Standards in accordance with Resolution 3, requesting that the Bureau "maintain as its working candle from this time on until definite international action shall have been taken, a candle unit two (2) per cent. lower than that which it is maintaining at the present time."

The sub-committee on Nomenclature and Standards is authorized to report further that the Bureau of Standards has already entered into negotiations with the foreign laboratories in regard to the possible agreement upon an international unit of luminous intensity, and that the hope is expressed that final agreement may be reached very shortly.

DISCUSSION.

Dr. E. P. Hyde:—Of course we all agree with the argument that it would be a good thing to have a common national and international unit of candle power. It would be well if, when we are speaking of photometric measurements of gas and electric lamps, or are speaking of photometric measurements made in this country or abroad, we can use always the same language. However, it is a far reach from a purely academic conception of the desirability of such a condition to the practical realization of it. Much credit, I think, is due to the Illuminating Engineering Society for taking the initiative in this matter, and much credit also is due to the American Institute of Electrical Engineers, and to the American Gas Institute for the cordial reception which they accorded the overtures of the Illuminating Engineering Society in this matter, and for the great consideration which they have given to the subject. Personally I feel profoundly appreciative of the attitude which the industries in this country have taken toward this movement. Many of them have heartily endorsed the movement, and are backing it at no little inconvenience and expense to themselves. The campaign, however, is not over even in this country, and I sincerely hope that every member of the Illuminating Engineering Society will do his utmost to see that this movement, which is the first in which the Illuminating Engineering Society has taken a definite initiative, may be crowned with success.

Dr. Louis Bell:—Personally, I feel that the outlook is bright for an international standard at a very early date. I got in touch with some of the representatives of the various interests abroad, and found them most sympathetic in Germany and in France. Everybody seems to feel that the time is ripe for a definite movement, and I have very little doubt that Dr. Humphreys will be able to push along and bring through this real reform ; it should have been done before this, but the data were not ready, and what was everybody's business was nobody's business. There was no one to take the initiative, and I believe that one of the most important things that the Illuminating Engineering Society has done is to put itself in a position to take the initiative in a movement of this kind.

MODERN GAS LIGHTING CONVENIENCES.[1]

BY T. J. LITLE, JR.

Modern incandescent gas lamps have reached such a high state of perfection and efficiency that it is well to direct attention to the various inventions and improvements that have been made for their ignition and control. These devices have naturally greatly popularized the gas system of lighting in the last few years, as it is generally conceded that when the proper methods are employed, illumination by gas is beyond criticism, due to the remarkably perfect combustion in the modern burner,

Fig. 1.—Cabinet Containing Jump Spark Lighting Equipment.

resulting in a greatly increased lighting efficiency, thus requiring fewer units than heretofore; moreover their more satisfactory color value must not be overlooked.

The modern ignition of gas burners may be accomplished in various ways, but it may be divided broadly into two general classes; namely, electric and pilot flame.

The electric spark ignition may again be divided into two classes, the jump spark (high-tension) ignition, and the interrupted-circuit low-tension (make-and-break) ignition. They may be further divided into other classes, differing somewhat in mechanical detail, but the following remarks will be confined to those above stated.

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

JUMP SPARK ELECTRIC IGNITERS.

The jump-spark igniting system is used where a large number of burners are to be ignited simultaneously, such as in store windows, store interiors, churches, public halls, factories, etc. In this case use is made of an induction coil of such a size as to

Fig. 2.—Lobby of American Academy of Music, Philadelphia. Lighted with Inverted Gas Lamps.

produce a spark of sufficiently high potential to jump the distance equal to the sum of the air gaps in the circuit. On account of its high potential, great care must be exercised to prevent leakage in the secondary circuit. To obtain good results not less than six standard dry cells should be used in the primary circuit. The push buttons may be located at any convenient points. For greater convenience, however, the whole electric outfit may be placed in a cabinet that is completely wired,

and all that is necessary on installation is to run the secondary leads from the cabinet to the burners. Such a cabinet is illustrated in Fig. 1, while Fig. 2 shows a very successful application of this form of ignition in the lobby of the Academy of Music, in Philadelphia. The hundreds of inverted lamps which are used there are centrally controlled by grouping the gas pipe circuits, as well as the secondary circuit of the jump-spark ignition system.

In addition it may be mentioned that with this system any number of lamps may be ignited by a division of the secondary circuit; that is, if the rating of the coil is 20 burners, all that is necessary is to divide the lamps into groups of 20. The wire used in the secondary circuit may be very fine; phosphor bronze of No. 30 gauge, on account of its great tensile strength, has been very successfully used. This wire may be suspended from burner to burner, being practically invisible. In this case use is made of the secondary distribution switch shown in the upper right hand portion of the cabinet. The gas is usually controlled mechanically, either by providing a gas cock adjacent to the spark cabinet, or if the cabinet happens to be at an inaccessible point, the cock may be operated from a distance by a mechanical pull device. The latter system has been used quite extensively where the existing gas piping was not conveniently arranged for the placing of the shut-off cock.

AUTOMATIC ELECTRIC IGNITER.

The automatic electric igniter for an upright burner is shown in Fig. 3. With this attachment it is possible to place push buttons at any distance from the burner for igniting and extinguishing. The small magnets in the cylindrical shell open and close the gas cock, and the vibrating make-and-break produces the igniting spark. The ignition of the burner in this case is accomplished indirectly by the climbing flash-pilot, which remains flashing only so long as the ignition button is pressed.

PENDANT ELECTRIC IGNITERS.

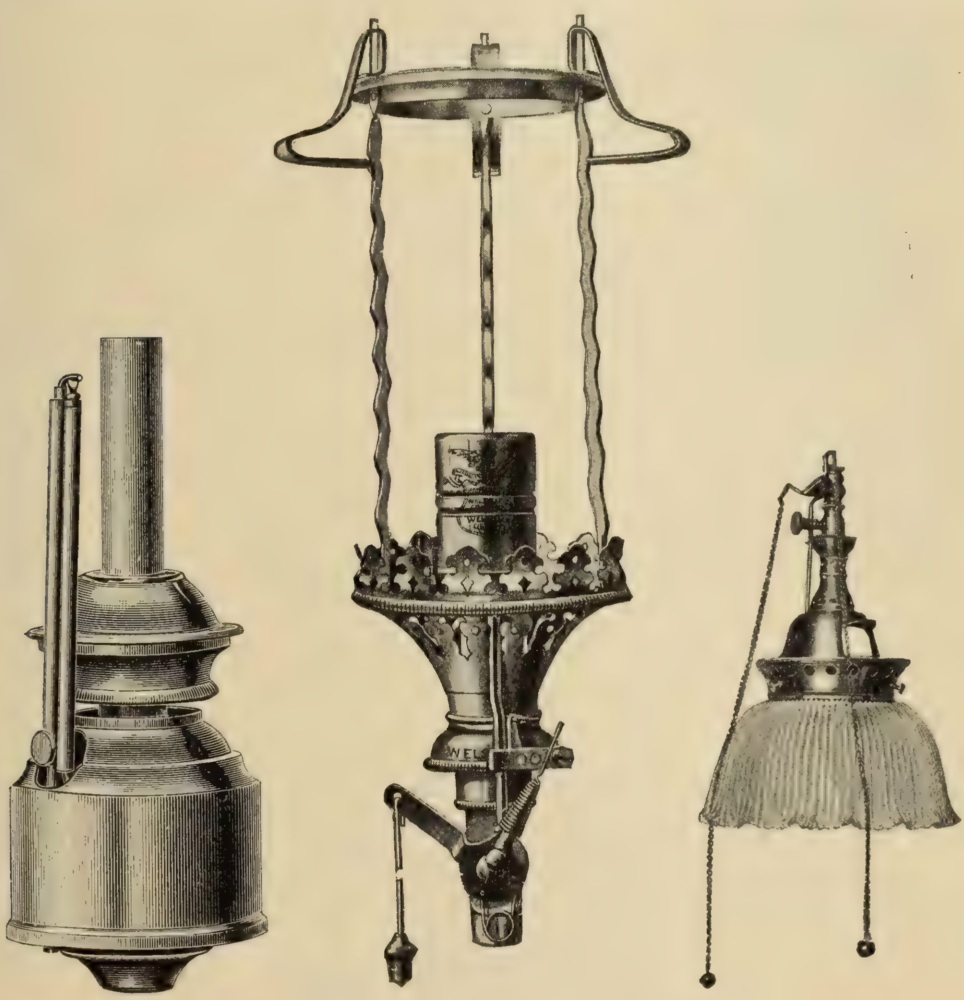
The pendant, or pull type of igniter, is operated at the burner; it consists of simply a gas cock to which is attached a pulling lever and an arm carrying a wiping sparker, which ignites a flashing pilot. In this case pulling down on the lever turns on and

ignites the gas, while pushing up the lever closes the cock. See Fig. 4.

The above two igniters are designed principally for residence use.

PILOT IGNITION.

The pilot system of igniting gas burners on account of its simplicity, is probably the most widely used of all. See Fig. 5. In this case a very small jet of gas is maintained at the end of a



Figs. 3, 4 and 5.—Types of Gas Lamp Igniters.

small pilot tube adjacent to the mantle. The gas cock is operated by means of chains. This system is generally adapted for residence lighting. The pilot flame is so situated as to be well protected from ordinary drafts, and the consumption of gas is so slight ($^1/_{12}$ cu. ft. per hour) as to be practically negligible. This

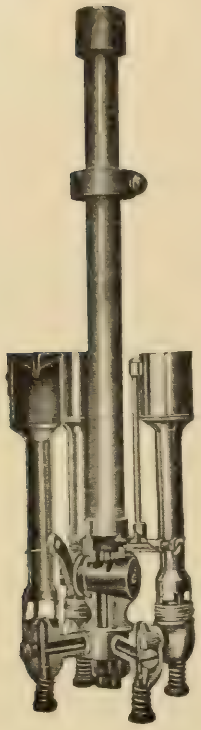


Fig. 6.—Section of Gas "Arc" Lamps.

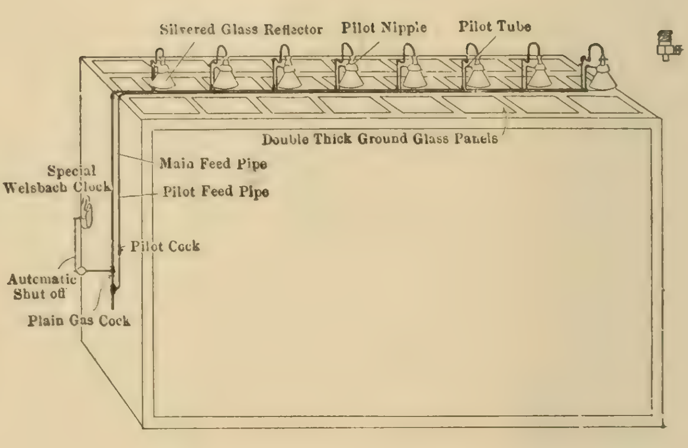


Fig. 7.—Independent Pilot System of Ignition.

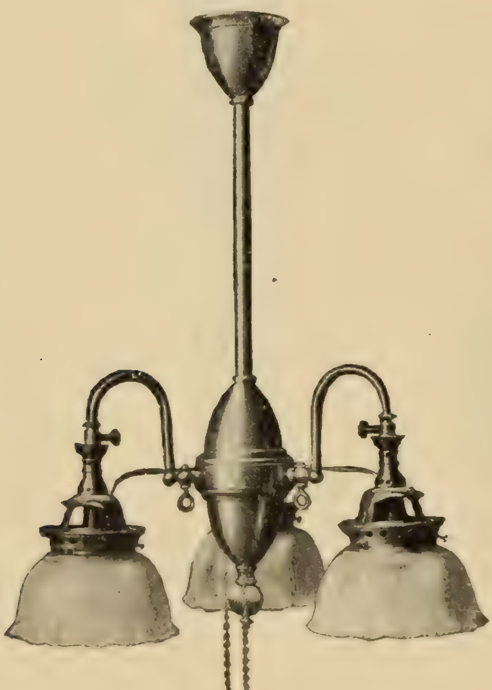
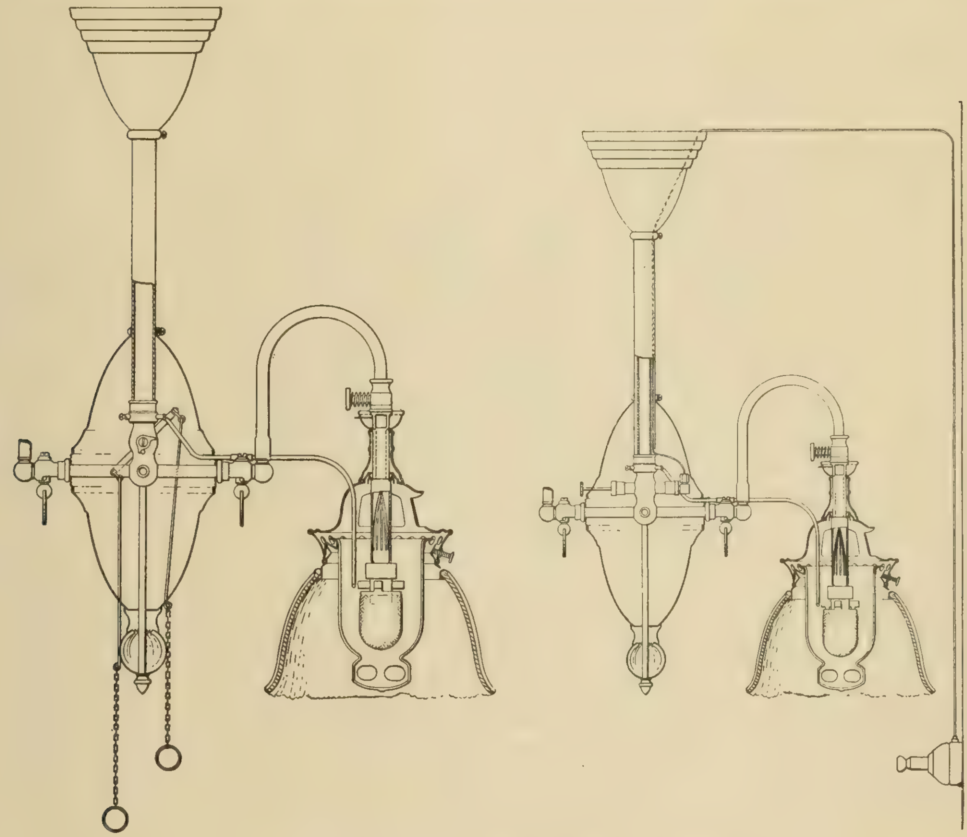


Fig. 8.—Gas Lamp Cluster.

system has been utilized very successfully on gas "arc" lamps, a sectional view of one of which is shown in Fig. 6.

MULTIPLE PILOT IGNITION.

Under this heading may be mentioned the application of pilot ignition for a large number of burners, as shown in Fig. 7. In



Figs. 9 and 10.—Gas Lamp Ignition Schemes.

this system the pilots for igniting the burners are supplied with gas from an independent feed line, and in igniting it is necessary merely to turn the gas on to the main supply pipe feeding the burners; when the gas reaches the mantles it is ignited by the pilots.

AUTOMATIC CLOCK CUT OFF.

In conjunction with both of the above systems, the automatic clock cut off is adapted to show-window and other forms of lighting where it is desired to extinguish the light automatically at any predetermined time. In this case the main shut-off cock supplying gas to the burners is provided with a weighted lever

which is held in its open position by means of a chain attached to a catch in the rear of the clock, and when the clock train starts in motion this chain is removed from its supporting hook and the gas cock closes. This operation may be reversed, so that the lamps may be ignited at any predetermined time.

PILOT IGNITION FOR CLUSTERS.

The latest application of the multiple pilot system of ignition is shown in Fig. 8. In this case several inverted burners are

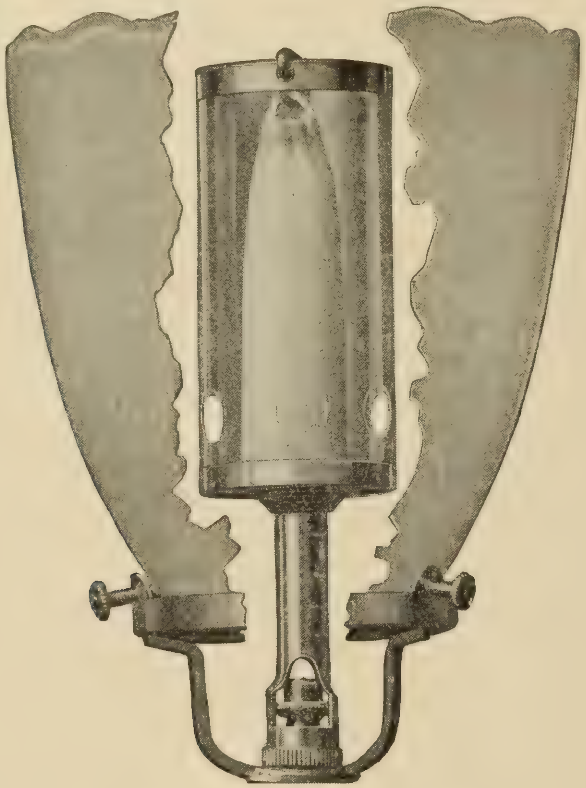


Fig. 11.—Miniature Gas Lamp.

supplied with gas for pilots from a point immediately above the shut-off cock, which is concealed within the shell of the fixture, as shown in Fig. 9. The gas is ignited by pulling the white ring, which depends from the fixture. This arrangement is decidedly convenient for the shop-keeper.

PNEUMATIC PILOT IGNITION OF CLUSTERS.

In this case the lamps are ignited in very much the same manner as in the case above mentioned, but the gas is controlled by a pneumatic cock, as shown in Fig. 10. A small copper tube

runs from the chandelier to the operating push button, which is in reality a small plunger pump. On pushing the plunger inwardly, air compressed along the entire line advances the piston valve, thus opening it; in order to extinguish, the plunger is pulled outwardly, thereby creating a partial vacuum and the pis-

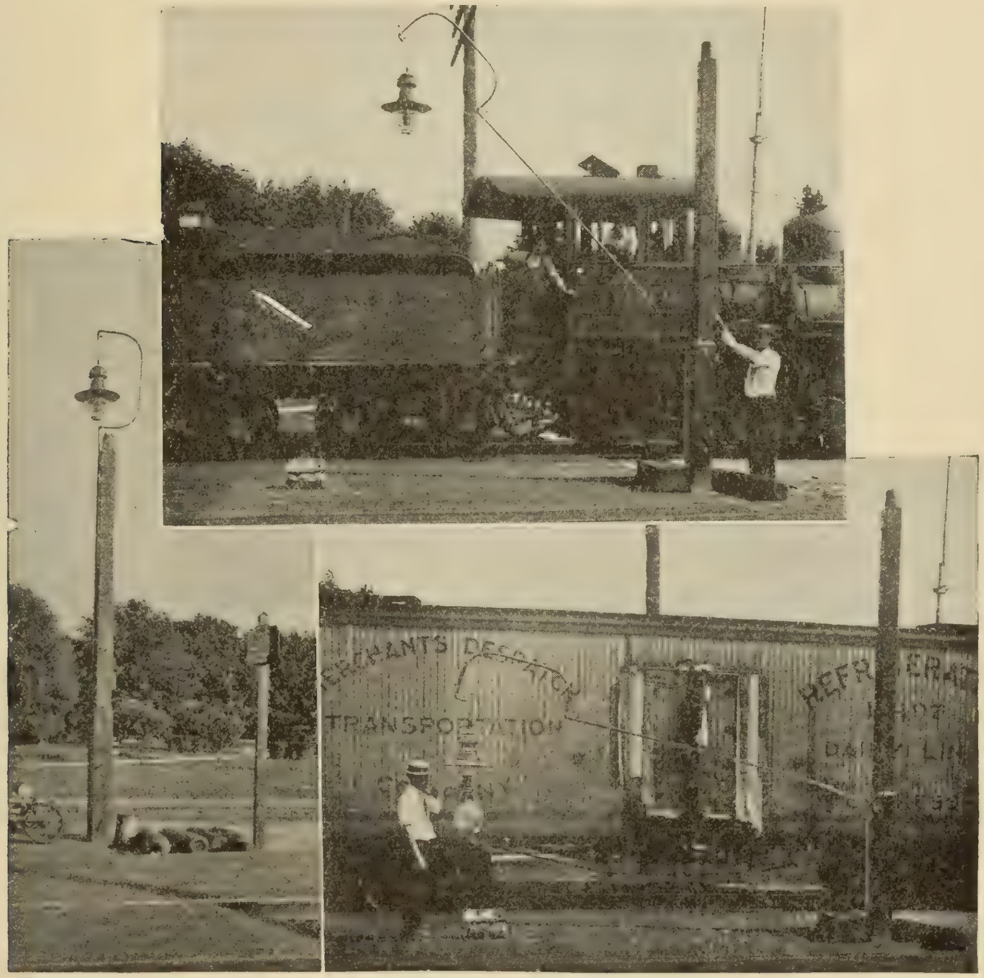


Fig. 12.—Railroad Lighting by Gas "Arc" Lamps.

ton valve is moved into the closed position. In addition to being able to ignite and extinguish the gas from a distance, it is also possible to do so at the fixture, as the plunger is equipped with an extension terminated by a push button which projects through the shell, and this may be operated by hand. The pneumatic lighter is also applied very successfully to single burners,—both upright and inverted.

MINIATURE GAS UNIT.

Under the heading of convenience may be mentioned the mantle arranged within a small mica chimney. It is provided in this form as a unit, which enables the consumer at one appli-

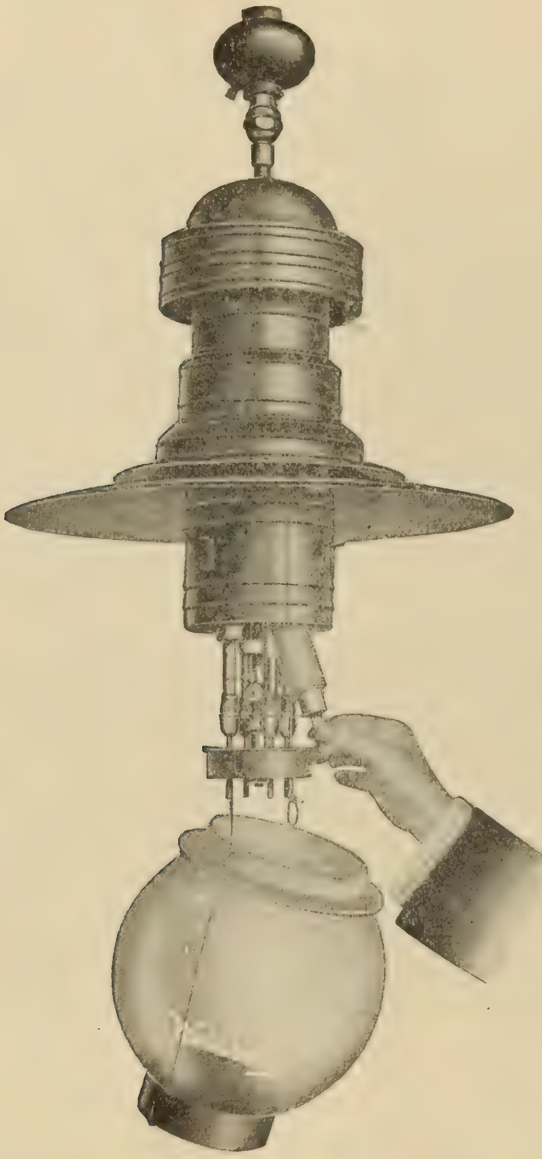


Fig. 13.—Gas "Arc" Lamp with Globe.

cation to renew the mantle and obtain a new mica chimney. This result is rendered possible on account of the small size and consequent cheapness, just as is the case with the carbon filament lamp. These units consume less than 2 cu. ft. of gas per hour,—to be exact, 1.69 cu. ft., under two inches of gas pressure. The

widespread application of this small unit can be readily appreciated when it is shown that the output is actually 51 candle-power with the above named consumption. It is admirably adapted to residence lighting, where small units are desirable.

It may be used in place of the lava-tip burner without affecting the symmetry of the fixture. Standard electric glassware may also be used with it, as shown in Fig. 11; on this account

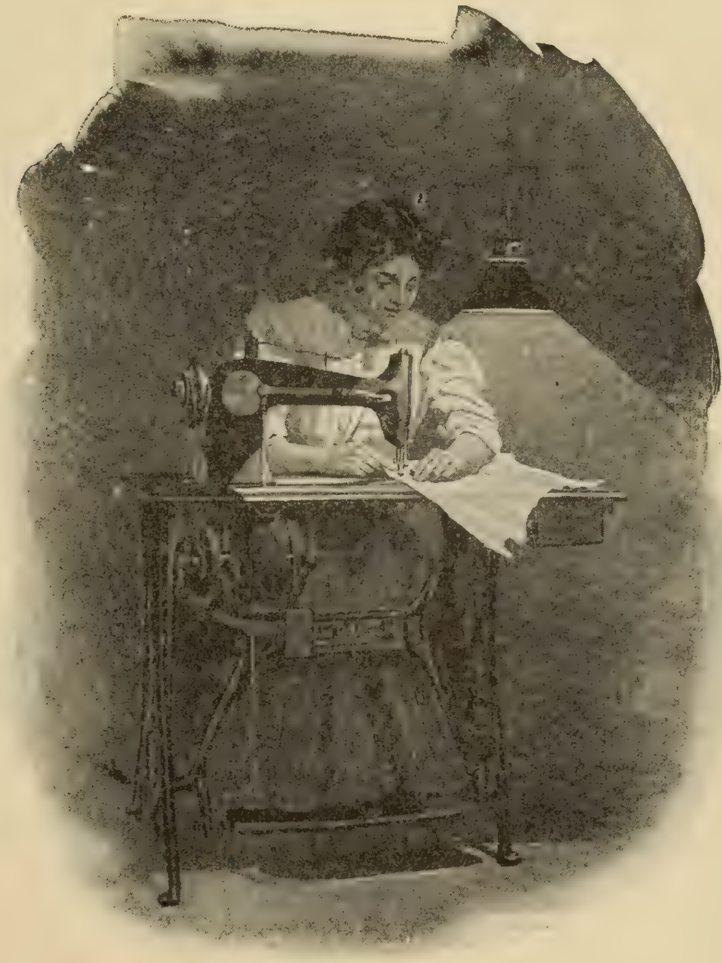


Fig. 14.—Application of Inverted Gas Lamp to Domestic Use.

is well adapted for combination gas and electric fixtures. The chain pull by-pass, with side pilot, may be applied to this unit.

MISCELLANEOUS.

So far the remarks have been confined to the various igniting schemes for incandescent gas burners; a great many ingenious devices have also been employed in

connection with gas "arc" lamps, as for example that shown in Fig. 12, for outdoor use, such as in railroad stations and yards. In this case the "arc" lamp is attached to a mast-arm device, the operation of trimming the lamps being as shown in the cut. Another convenient application employed with the outdoor lamp is illustrated in Fig. 13, where the globe has been lowered onto the hook below the lamp and the operation of replacing a mantle is shown. The remaining mantles are protected from the wind by the cylindrical shell which automatically follows the globe on its removal.

Flexible metallic gas tubing has been very generally adapted for use in connection with inverted burners. This tubing is made by spirally winding a corrugated metallic ribbon, with asbestos cord intervening, to make the joint gas-tight the corrugations serving not only to retain the asbestos cord but at the same time locking together the convolutions. In machine shop practice these tubes are suspended either from an overhead stationary gas pipe or from an inverted swing gas bracket. The latter makes it possible to shift the lamp over a considerable area. This device as adapted to domestic use is shown in Fig. 14.

DISCUSSION.

Dr. Clayton H. Sharp:—Have there been any modern developments or improvements in electric igniters which will prevent their getting out of order? As I take it, the chief reason for the failure of electric gas igniting systems is the lack of insulation somewhere in the electrical system, so that it seems to me that the problem resolves itself largely into a question of proper insulation against the high electrical tensions which are involved, either in the jump-spark ignition, or in the make-and-break system. I have seen electrical gas igniting systems installed in which a single or double cotton covering on the wire was relied upon for insulating purposes. An insulation of this kind would not be expected to give satisfactory results in any electrical lighting system where only moderate tensions of 100 or 200 volts are involved. We all know that to produce the spark necessary for electrical gas ignition, considerably higher tensions must be produced, consequently use must be made of a degree of

insulation which corresponds thereto, and the older gas igniting system certainly did not have this.

I should also like to ask regarding the pilot ignition system, whether there is any possibility of danger due to the extinguishment of the pilot flame by draughts of air or in other ways, perhaps by clogging of the pipe, in a closed room where the gas is allowed to stream forth freely without being burned. Is there not danger where water gas is used rather than old fashioned coal gas?

Mr. F. N. Morton:—Mr. Litle spoke of the lack of development of the self igniting mantle. Can he tell us in what stage of development that is, whether experiments on it have been abandoned it, or whether there are yet hopes of perfecting the device? There is another type of igniter which is not mentioned here, and that is the Welsbach alloy igniter. I should like to know if he has any expectation of developing that igniter.

Mr. V. R. Lansingh:—Are the fixtures made today so that the pilot flames on three burners, on a four-lamp fixture, can be cut off and only one flame burned if necessary? It often happens that on a four-lamp chandelier the people want to use only one lamp, and do not want to have the other three pilots burning. While the consumption is small per hour, in the course of a year it amounts to a good deal. In the fixtures which I have seen it is impossible to do anything but burn all four pilot flames.

Mr. H. Calvert:—To what extent can the pneumatic pilot system of ignition shown in Fig. 10, be carried in practice? That is to say, how many burners can be operated at one time, and how long can it be used? How great can the distance be from the fixture to the operating button?

Mr. Walton Forstall:—I wish to offer testimony regarding the reliability of the pilot flame. Last spring an inverted gas lamp was installed in a room where later on in summer weather the windows were open constantly. From the time of installation of the lamp until about two weeks ago, this period including an absence from the house of the entire family, the pilot flame was never out, and it would have been burning until this moment if the gas had not happened to be shut off from the house, due to some necessary work on other burners. This shutting off

of the gas enables me to give testimony on another point in connection with the pilot flame, and that is that its consumption of gas is too slight to make an objectionable leak, for in the case above I did not know that the flame had gone out and had not been reignited until about two days afterwards, when the only evidence was a slight leak that at times could be smelled and at times could not.

Mr. Fritz Beck:—I may be able to give a little information in regard to the question asked by Mr. Calvert. The distance on which the pneumatic gas lighter can be operated successfully, with the kind of the tube now generally used, is about twenty yards for one lamp. The number of lamps to be supplied by one tube is about six, the distance diminishing with the number of lamps included in one circuit. The tube which supplies gas to the igniter is very thin, about one-sixteenth of an inch, and has the advantage over electric wiring that it does not need any insulation. There is no danger of fire, or getting out of order through lack of insulation, as is the case with the electric gas igniter.

It has another advantage which will probably induce many people to use pneumatic control instead of electric ignition, and that is the simplicity of its parts. It really consists of only a valve, a tube and a pump, all of which are generally familiar to every man, while electrical appliances always require the services of more or less of an expert for their installation and maintenance. In the latest design of the pneumatic valve the most important part, which is the piston in the valve, is really made visible, so that at a glance any user of this system can see whether the valve works successfully or not, and can operate it at the burner or pneumatically from a distance. Another advantage of the pneumatic ignition, which the electrical ignition does not possess, is that the number of lamps to be turned on or off is under the control of the operator. On a chandelier of six lamps it is possible to turn on one lamp after the other or all at once from one push button or ball pump simply by pulling the push button, or pressing the ball more or less. It is these little things which win the favor of the public more than anything else. Although for ignition of a great number of lamps simultaneously, electrical ignition is probably the best,

in general residence lighting it cannot compete successfully with the pneumatic system.

Mr. C. W. Hare:—We have heard a very short discussion of what ought to be a really successful piece of apparatus, and I should like to learn of the experience of some one who has observed the system working practically somewhere. Is there anyone here who has tried this system and found its defects? If there are defects, let us know them. If there are no defects, we should learn that fact.

Mr. N. W. Gifford:—I can say for Mr. Hare's information that I know of a case where a number of installations of the independent pilot ignition system have been in use for a considerable number of months without any complaint. Use is made of the independent pilot flame, the burner being installed in the usual way, and a line is run from an independent line to the pilot tube, the pilot flame of course, burning continuously. The burners are turned on and off as they are wanted.

President Bell:—The Chair can partly answer from his personal experience one question which has been raised, by saying that the average electric gas ignition system is installed without any due regard to insulation, the common arrangement being a signal bell system, usually with single cotton insulation. It is not in the least remarkable that such a system should be a failure. In the absence of any further discussion I ask Mr. Litle to close the discussion, and particularly to give us what information he can about the practical working features of that beautiful alloy of cerium and iron which Dr. Auer Von Welsbach, who is the one to whom both the gas and electric industries owe a great debt, has developed very recently.

Mr. Litle:—Probably the most pertinent question was that regarding the unreliability of electric gas igniters. I think, however, his question has been pretty well answered by some of the other speakers. It must be remembered that wiring for electric gas ignition is not in the same class as that for electric lighting, for the simple reason that there is no fire hazard, and it is only the high-potential jump spark systems that require careful insulation. With the low-tension system all that is necessary is to use a triple or a quadruple insulated conductor that is well water proofed. Of course care should be used that

the insulation is not cut by tacks or by coming in contact with sharp metallic edges. The trouble that has previously existed with electric igniting systems I think can be attributed mainly to two causes:

First, conductors poorly insulated and carelessly installed, and,
Second, defective and poorly constructed burners.

The most common burner defect was in the wiping contact device, which would stick in making contact and thus short circuit the batteries, which of course would render the system inoperative. There has also been a great improvement in the manufacture of primary batteries, particularly those of the "dry" type.

Dr. Sharp has asked what danger exists in connection with the pilot flame gas igniters,—whether the blowing out of the flame would be a source of danger. In the first place these pilots are so located in the burners that they seldom blow out, unless placed in a strong draft—such as directly in line with an open window. Personally I have had very little trouble of this kind. However, if the insignificant amount of gas that is burned by the pilot, namely, from 1/10 to 1/12 cu. ft. per hour, and also the natural ventilation of a room which is many hundred times as great, be considered it can be readily seen that there is no danger, and as one gentleman has just testified, it is very seldom that such a small flow of gas is at all noticeable, due as stated above to the natural ventilation, from around windows and doors and through the walls. Under these circumstances a gas explosion due to leakage from pilots is hardly possible.

In answer to Mr. Morton's question regarding the self-igniting mantle, it may be said that such a mantle has not been developed sufficiently to warrant its being called commercial. A great many of these mantles have been sold in this country, as well as in Europe, but none is reliable, due no doubt to the action of the heat and products of combustion on the ignition material. Some of them will work perhaps for a couple of weeks, while others from the same lot will not operate at all. I am not able to state the exact cause.

In regard to the pyrophoric igniter, invented by Dr. Carl Auer von Welsbach, it is noteworthy that this is as yet in the experimental stage. It is an interesting alloy of iron and cerium, the

product of the electrical furnace, and is put up in the form of a little briquette that will emit a brilliant stream of sparks on being scratched with a sharp, hard surface. A shower of sparks will be given off by scratching it with the point of a knife. I believe it eventually will develop into a successful form of gas igniter.

Mr. Lansingh has asked about the ability of a consumer to turn off pilots in case he needs not more than one on a fixture. I suppose he refers to the inverted chandelier, equipped with pilot by-pass. Each pilot is regulated independently by an adjusting screw and the gas may be shut off by turning the screw all the way in; by the aid of the cock in the fixture arm the gas may be turned off from the burner. This adjustment of course will not interfere with the working of the other burners and pilots.

I think Mr. Beck has fully answered Mr. Calvert's question regarding pneumatic lighting system, but I should like to add that this system has been greatly improved recently, by the substitution of a cork piston in the plunger push button, in place of the older type of leather washer piston.

President Bell:—I should fail in my duty were I not to compliment Mr. Litle on the extremely brief, frank and simple manner in which he has set out the possibilities of practical gas ignition.

THE ILLUMINATING VALUE OF PETROLEUM OILS[1]

BY DR. ARTHUR H. ELLIOTT

During the past few years, incidental to the author's work in photometry, he has had occasion to make a number of tests pertaining to the illuminating value of petroleum oils burned in various lamps.

The aim in this work was to secure some lamp or flame that would serve as a secondary standard for photometric work, and it appears that the data that were obtained during these experiments will be useful to others as well as the author. It seemed wise, therefore, to place on record in some detail the various experiments which were made with a number of lamps and also with various petroleum oils of high and low density.

In regard to the lamps used, the small lamps are found in commerce with glass reservoirs and 0.5-in. and 1.0-in. cotton wicks. Use was made also of lamps with two wicks, where in one case both wicks go through the same burner slot, and in the other case, each wick has a separate slot in the top of the burner. Two lamps with round wicks were also used.

The oils used have been the best grade kerosene oils of 48° to 50° Beaumé, and 150° flash; heavy burning oil, 40° Beaume, 300° flash; gas oil distilled to eliminate residuum, of 35° Beaumé; and a mixture of kerosene oil with heavy 300° flash oil, the mixture having a density of 45° Beaumé.

In starting these investigations, the work done by others was naturally looked over and very little of this kind of work was found on record. The author may be unfortunate in his search, but that is the result of his investigation. He did find some work done by Stevenson Macadam, F.R.S.E., who about the year 1870 conducted some experiments on the illuminating value of mineral oils and compared them with sperm oil, rape oil (colza) and whale oil. It is unnecessary to go into detail with regard to these various oils, but Table A gives a résumé of

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

his results and a comparison of the mineral oils, with others mentioned.

In the investigations tabulated in Tables B, C, etc., which accompany this paper, two methods of procedure have been used.

Each lamp was tested against a pair of standard sperm candles, burning within the regulation limits of 120 grains of sperm for each candle per hour. The relative variation in the illuminating power was then calculated, designating the maximum illuminating power as 100, and the others as percentages. By this means it is seen at a glance just how the lamps vary in candle-power and to what extent.

Each of the readings across the table indicates hourly observations, and it will be seen that in many cases these observations run over a large number of hours. Moreover, the quantity of oil, in grains, burning one hour, to give one candle-power, was calculated, in order to compare it with the standard sperm candle—the light obtained from sperm burned at the rate of 120 grains per hour. This gives a direct comparison between sperm and the same weight of any oil used. Some of these figures are extremely interesting, as indicating the high value of petroleum oils of good quality, as compared with sperm oil.

It is rather remarkable in looking over these tables to note the steadiness and reliability of the flat-flame lamps, even when burned with common reservoirs where the level of the oil varies as the lamp burns ; it will be noted that the rate of consumption and the candle-power are extremely constant. Many of the lamps used gave nearly twice the candle-power of sperm candles for the same weight of oil, while the round-wick lamps gave fully three times as much.

In the early experiments the lamps were adjusted by the eye ; that is to say, the height of the flame was determined and not changed during the experiment, attention being paid only to obtaining the best light. In later experiments, a wire gauge above the flame served to determine its height in the case of flat-flame burners ; this arrangement was found impracticable with the round burners. Under these circumstances, it was found that a flat-flame burner would operate several hours with a loss of less than five per cent. in its candle-power, and in many cases only two or three per cent. The form and height of the flame, of

course, determine its candle-power, but this condition was not considered of so much importance as obtaining a steady flame burning at a uniform rate and giving a constant candle-power. The trimming of the wick determines the shape and height of the flame and also its freedom from smoke. Many of the lamps of flat-flame without any adjustment of level in the reservoir, were used for as long as seven hours with a change of less than five per cent. in the candle-power.

As will be seen from the tables, the heavy oils cannot be burned in small, single-wick, flat-flame lamps, since the burning temperature of the cotton wick is lower than the burning temperature of the oil. Furthermore, the density of the oil prevents its rising sufficiently rapidly in such wicks. The experiments were therefore conducted with double wicks. These remarks are true of both the 300° flash oil and also the distilled gas oil.

In later experiments, a reservoir with a student lamp feed was used for the flat-flame burners ; in this case the light was constant over six or seven hours with a variation of less than one per cent. in the candle-power, tested by both standard sperm candles and also secondary standards and electric units. Even an oil as low in density as 44° Beaumé in seven hours lost only 5.5 per cent. of its photometric value. It was even found possible to place two lamps of the same photometric value opposed to one another on a photometric bench and obtain only 0.02 candle-power variation in five hours.

It is interesting to note (Table P) that the oil used in a lamp replenished from day to day during one week, is of practically the same character at the end of the week as it is at the beginning. This fact demonstrates that the wicks carry the oil uniformly and do not separate the various constituents of the oil, and fully accounts for the uniformity of burning and constant candle-power.

From the tables given, very interesting calculations can be made as to the value of oils used in various ways, and also in comparison with other illuminants. These calculations and deductions will be left to others. The author simply desires to place on record here some results of the large amount of interesting work that has occupied what spare time he could give to ti during the past three years. He has been fortunate in having

the resources of the Consolidated Gas Company of New York at his disposal, and also three assistants, Messrs. Ihart, Regan and Morhous, to whom he tenders his sincere thanks for their cordial co-operation.

TABLE A—ILLUMINATING VALUE OF OILS. MACADAM.

Lamp used	Small flat flame		Medium flat flame		Large flat flame	
Oil used	Grains per hour	Candle-power	Grains per hour	Candle-power	Grains per hour	Candle-power
Paraffine (Shale) Uphall & Young.	328	6·0	492	9·0	656	12·0
Value of 120-grns. of paraffine oil per hour	120	2·195	120	2·195	120	2·195
Sperm...........	180	1·306	—	—	—	—
Rape (Colza)	170·6	1·05	—	—	—	—
Whale...........	153	0·90	—	—	—	—

Lamp used	¾-in. Argand		1-in. Argand	
Oil used	Grains per hour	Candle-power	Grains per hour	Candle-power
Paraffine (Shale) Uphall & Young.	494	9·0	975	19·83
Value of 120-grns. of paraffine oil per hour.......	120	2·195	120	2·719
Sperm...........	—	—	1006	13·0
Rape (Colza)....	—	—	933·2	11.33
Whale	—	—	853	9·8

TABLE B—EXPERIMENTS WITH VARIOUS LAMPS, USING KEROSENE OIL

Oil not measured.

Burner used	Time	Candle-power	Illumination %
⅝-in.	10 minutes	5.59	90.7
"	2½ hours	6.16	100.0
"	4 hours	6.16	100.0
1-in.	15 minutes	8.64	98.5
"	1¾ hours	8.77	100.0
"	3¾ hours	8.56	97.6
1.5 in., with height gauge	10 minutes	6.88	98.00
" " " "	1 hour	6.79	96.7
" " " "	2 hours	7.02	100.00
1.5-in. wick, 1-in. height gauge. Student feed	10 minutes	11.76	93.5
1.5-in. wick, 1-in. height gauge. Student feed	1½ hours	12.51	99.5
1.5-in. wick, 1-in. height gauge. Student feed	3 hours	12.60	100.0

TABLE B.—(*Continued*).

Burner used	Time	Candle-power	Illumination %
1.5-in. wick, 1-in. height gauge. Student feed	5 hours	11.67	92.6
1.5-in. wick, 1-in. cut, height gauge	30 minutes	15.09	100.0
1-5-in. wick, 1-in. cut, height gauge	3½ hours	14.96	99.1
1.5-in. wick, 1-in. cut, height gauge	5½ hours	14.83	98.3
1.5-in. wick, 1-in. cut, height gauge	7 hours	14.52	96.2
1.5-in. wick, 1-in. cut, height gauge 1.5-in.	10 minutes	14.92	99.1
1.5-in. wick, 1-in. cut, height gauge 1.5-in.	2 hours	14.73	97.9
1.5-in. wick, 1-in. cut, height gauge 1.5-in.	5 hours	14.97	99.5
1.5-in. wick, 1-in. cut, height gauge 1.5-in.	7 hours	15.05	100.0

TABLE C—KEROSENE.

One ½-in. wick. 6 hours.

Oil per hour Grains	Candle-power	Variation of illuminating value
308.64	4.90	98.00
308.64	5.00	100.00
308.64	5.01	100.00
308.64	5.01	100.00
308.64	5.00	100.00
308.64	5.00	100.00
Average	4.987	99.70

1 c.p.-hour requires 61.98 grains of oil.

120 grains of oil per hour = 1.936 candle-power

Variation of standard during test, 10.25 to 10.21 c.p.

TABLE D—KEROSENE.

One 1-in. wick. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	617.28	10.83	98.71
	624.99	10.87	99.08
	617.28	10.87	99.08
	620.36	10.97	100.00
	617.28	10.97	100.00
	617.28	10.97	100.00
Average	618.98	10.913	99.48

1 c.p.-hour requires 56.71 grains of oil.

120 grains of oil per hour = 2.114 candle-power.

Variation of standard during test 10.18 to 10.14 c.p.

TABLE E—KEROSENE.

Two 1-in. wicks. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	540.12	8.83	200.00
	540.12	8.72	98.75
	540.12	8.72	98.75
	540.12	8.80	99.66
	540.12	8.80	99.66
	540.12	8.80	99.66
Average	540.12	8.78	99.413

1 c.p.-hour requires 61.51 grains of oil.
120 grains of oil per hour = 1.951 candle-power.
Standard unchanged during test.

TABLE F—KEROSENE.

Two 1.5-in. wicks. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	1208.32	22.60	98.70
	1208.32	22.70	99.13
	1208.32	22.70	99.13
	1208.32	22.80	99.56
	1208.32	22.80	99.56
	1208.32	22.90	100.00
Average	1208.32	22.75	99.35

1 c.p.-hour requires 53.11 grains of oil.
120 grains of oil per hour = 2.259 candle-power.
Variation of standard during test, 10.00 to 10.07 c.p.

TABLE G—KEROSENE.

One round wick 1.5-in. diameter. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	1898.17	34.4	99.71
	1898.17	34.2	99.13
	1898.17	34.5	100.00
	1898.17	34.1	98.84
	1908.17	34.2	99.13
	1898.17	34.2	99.13
Average	1898.17	34.266	99.32

1 c. p.-hour requires 55.40 grains of oil.
120 grains of oil per hour = 2.166 candle-power.
Variation of standard during test, 10.12 to 10.00 c.p.

TABLE H—KEROSENE.

One round wick, 1⅛-in. in diameter. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	1539.11	39.5	99.49
	1539.11	39.6	99.75
	1539.11	39.6	99.75
	1539.11	39.6	99.75
	1539.11	39.7	100.00
	1539.11	39.6	99.75
Average	1539.11	39.6	99.75

1 c.p.-hour requires 38.86 grains of oil.
120 grains of oil per hour = 3.08 candle-power.
Variation of standard during test, 10.08 to 10.01 c.p.

TABLE I—SUMMARY OF SIX-HOUR TESTS. KEROSENE.

Burner used	C.	D.	E.	F.	G.	H.
Size of wick	½-in.	one 1-in.	two 1-in.	two 1.5-in.	1.5-in.	1⅛-in.
Grains oil per hour..	308.64	618.98	540.12	1208.32	1898.17	1539.11
Average candle-power	4.987	10.913	8.78	22.75	34.26	39.60
Average per cent. illumination	99.70	99.48	99.41	99.35	99.32	99.75
One c.p.-hour requires grains of oil.......	61.98	56.71	61.51	53.11	55.40	38.86
120 grains of oil per hour = candles....	1.936	2.114	1.951	2.259	2.166	3.080

TABLE J—300° FLASH OIL, 40.4° BEAUMÉ.

Two 1-in. wicks. 4 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	459.87	6.34	100.00
	459.87	5.73	90.3
	462.96	5.93	93.5
	450.71	5.56	87.7
Average	457.85	5.890	92.9

1 c.p.-hour requires 77.7 grains of oil.
120 grains of oil per hour = 1.544 candle-power.
Standard unchanged during test.

TABLE K—OIL MIXTURE, (HALF KEROSENE, HALF 300° FLASH),

Mixture = 44.5° Beaumé at 60° F.

Two 1-in. wicks. 4 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	544.75	9.01	100.0
	544.75	8.93	99.1
	544.75	9.01	100.0
	544.75	8.91	98.9
Average	544.75	8.965	99.5

1 c.p.-hour requires 60.8 grains of oil.
120 grains of oil per hour = 1.975 candle-power.
Standard unchanged during test.

TABLE L—OIL MIXTURE, (HALF KEROSENE, HALF 300° FLASH).
One 1-in. wick. 4 hours.
Mixture = 44.5° Beaumé at 60° F.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	552.46	7.70	100.0
	552.46	7.65	99.3
	540.12	7.15	93.0
	535.49	7.00	91.0
Average	542.69	7.375	95.8

1 c.p.-hour requires 73.6 grains of oil.
120 grains of oil per hour = 1.630 candle-power.
Standard unchanged during test.

TABLE M, OIL MIXTURE, (HALF KEROSENE, HALF 300° FLASH).
STUDENT FEED.
One 1.5-in. wick. 7 hours.
Oil mixture, 44.5° Beaumé.
Tested for variations of candle-power with time.

Time	Candle-power
9 : 30 A. M.	15.05
10 : 30 "	14.85
11 : 30 "	14.43
12 : 30 P. M.	14.43
1 : 30 "	14.33
2 : 30 "	14.33
3 : 30 "	14.23
4 : 30 "	14.23
7 hours	14.485 Average c.p.

Maximum candle-power........... 15.05
Minimum candle-power 14.23

Variation of candle-power .... .82
Variation 100 to 94.55.
Standard unchanged during test.

TABLE N—GAS OIL, (DISTILLED), 35.3° BEAUMÉ, 0.847 SPECIFIC GRAVITY.
Two 1-in. wicks. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	578.70	8.18	100.0
	578.70	8.18	100.0
	578.70	8.18	100.0
	578.70	8.18	100.0
	578.70	8.12	99.26
	578.70	8.12	99.26
	578.70	8.12	99.26
Average	578.70	8.16	99.68

1 c.p.-hour requires 70.9 grains of oil.
120 grains of oil per hour = 1.692 candle-power.
Variation of standard during test, 10.32 to 10.30 c.p.

TABLE O—GAS OIL, (DISTILLED), 35.3° BEAUME, 0.847 SPECIFIC GRAVITY.

Two 1.5-in. wicks. 6 hours.

	Oil per hour Grains	Candle-power	Variation of illuminating value
	657.4	14.40	100.0
	657.4	14.30	99.3
	640.4	14.10	98.0
	632.7	13.70	95.1
	617.3	13.40	93.0
	617.3	13.20	91.6
	617.3	13.10	91.0
Average	630.4	13.74	95.4

1 c.p.-hour requires 45.9 grains of oil.

120 grains of oil per hour = 2.614 candle-power.

Variation of standard during test, 10.00 to 10.06 c.p.

TABLE P—LAMP ONE WEEK BURNING, USING KEROSENE, TEST OF VARIATION OF OIL.

Oil at start, 49.1° Beaumé, 60° Fahr.
Oil at finish, 49.0° Beaumé, 60° Fahr.

DISTILLATION.

	320°–400° F.		400°–500° F.		500°–600° F.		Residuum 600°–660° F.
Start,	47.2%	52° Bé	42.8%	47° Bé	6.8%	41.0° Bé	3.2%
Finish,	46.0%	52° Bé	42.0%	47° Bé	10.0%	41.5° Bé	2.0%

DISCUSSION.

Mr. N. W. Gifford:—Dr. Elliott neglected to state that his standard is already in quite general use for a working standard. I know that in the work of which I have charge there are a great many photometric observations taken every week with his standard as the basis.

Mr. C. O. Bond:—I have had some experience with the oil lamp, chiefly with Dr. Elliott's lamp having the student feed principle and a flat wick. The flat wick type is the only one I have tested out, and the author's conclusions are borne out in my case also—that up to ten hours it gave a very satisfactory light. I was in hopes that we could get a lamp which would burn longer than that with a constant value. After twenty-four hours, I find that there is in most cases a rather heavy incrustation of the wick, where it chars on being exposed to the flame. On several occasions, where the lamp has burned continuously, at the end of from eighteen to twenty hours, the chimney cracked, evi-

dently due to the fact that as the incrustation progressed and the flow of oil through it became more and more difficult, the oil would apparently flow through the path of least resistance, usually at one side of the wick, causing there a flame of exaggerated length, which would impinge on the chimney, and crack it through the effect of local heating. Of course, it also had the result of smoking the interior of the chimney, more or less, although as a rule above the point where it would do any harm in the way of diminishing the light.

Of course, any oil lamp will be open to the two objections to be avoided in standards of light, first that it has a wick feed, and especially in this case a wick feed where the flame is in direct contact with the wick, and not, as in the case of the Hefner lamp, or some of the pentane lamps, where the wick is practically not in contact with the flame. Secondly, that it is surrounded by a glass chimney, and this glass chimney must be closely watched to see that there is no collection of an oily layer either from the products of combustion or working up from below, as might be the case if the lamp were too long in use.

The determination of the length of time that this lamp can be burned and called an authoritative standard is important. If one can be sure that it will burn for ten hours, without any correction, beyond a half of one per cent., or one per cent., well and good ; but if at the end of twenty-four hours it has lost four, or five, or six per cent. in value then it will be necessary to work out the curve and find what percentage was lost at ten, twelve and fifteen hours, or whether the loss is proportional to the elapsed time.

In my own experience the lamp was not as regular as desirable, as sometimes it burned twenty-four hours with a comparatively large per cent. of loss, and at other times with a small one. The lamp I tried was a ten-candle unit. Dr. Elliott now has one in which the amount of flame exposed to view through the diaphragm is equivalent to about a five-candle lamp. Perhaps he has secured better results from this lamp.

The Hefner lamp is excellent, but gives too small a light unit for practical purposes. It is a unit, but it is not a working standard. The pentane lamp has some objections ; it is expensive to maintain as compared to a kerosene lamp. There has

been difficulty up to date in the shipment of pentane. The lamp is expensive also in first cost as compared to the lamp which Dr. Elliott has suggested.

This is a good field for investigation, if an oil standard is found it certainly ought to be of a great deal of use to illuminating engineers when they are far removed from their base of supplies and cannot get a more constant standard.

Mr. R. C. Ware:—Has Dr. Elliott experimented with asbestos wicks, to get rid of the charring? I suppose there is a certain amount of carbonization, due to the burning of oil itself, but it seems to me that it is possible to eliminate a great deal of the charring by using a non-combustible wick.

Mr. N. A. Dutton:—Is it not a fact that a lamp will burn as readily with as little loss of efficiency twenty-four hours as ten hours, provided the reservoir is supplying the oil constantly at a uniform distance from the flame, as a student lamp properly constructed with a constant flow of oil should do? A reservoir, holding oil sufficient to burn twenty-four hours, would be rather unsightly, and would not be considered a commercial article. The reservoirs, as made today, are expected to hold enough oil to last at least two evenings. If oil is drawn for more than six inches, there is danger of charring the wick, which of course would diminish the intensity of the flame and leads to its smoking.

Dr. E. P. Hyde:—There is one point to which I think reference might be made in this connection—if the lamp is to be used as a working standard, and is not to be depended upon for an absolute value of light, it would have to be standardized in position probably, after the wick was trimmed. I do not see off hand, what the objection would be to re-standardiziug it two or three times a day. Why should it have to burn indefinitely, in order to be a satisfactory working standard?

I have had no experience with the lamp myself, but I am very much interested in the development of a suitable working standard for gas and, therefore I should like to ask Dr. Elliott, first, whether one can depend upon the absolute value of the light from the lamp, provided he uses the same oil and the same kind of wicks without having to recalibrate it? If it is possible to do so, then one can trim the wick from time to time. If not, it

must be standardized anyhow, and it seems to me that it is not a very great objection to the lamp that it must be standardized two or three times during the day.

In photometry of electric lamps, I do not believe it is uncommon to check up the comparison lamp several times a day in order to see that it has not changed, and in the case of a flame comparison source the wick might be retrimmed and the lamp restandardized at intervals. If it runs perfectly constant for eight or ten hours, it seems to me it is well worthy of further consideration as a secondary or working standard in gas photometry.

Mr. E. L. Elliott:—Is the change in candle-power due to a change in the size of the flame, on to a change in the specific brilliancy of the flame?

President Bell:—Would there be any advantage in the use of a specific hydro-carbon, easily obtained, or in the use of a flat quartz plate without a screen or chimney in order to avoid danger in cracking the chimney and to give a more uniform flux of light through the specified area?

Dr. A. H. Elliott:—Answering Dr. Bell's question first, I will say that the use of a definite hydro carbon is not necessary. Use has been made of hydro carbons or kerosene oils as low as 45° Beaumé, and there was obtained a light within two or three per cent. of the light with oil of 50° Beaumé. The hydro carbons that are 45° Beaumé have a much lower burning point than those of 50° Beaumé, and they are very heavy, probably dodecane in the paraffin series.

The time of test mentioned in the paper was ten hours, because that was the longest period over which I have made experiments but in one of the gas companies in Greater New York, where the lamps are fed from reservoirs that hold oil for twenty-four hours burning, the candle-power of the lamp drops only .2 or .3 candle in that time. A certain lamp used for two months, worked by two men who standardized it night and morning, showed a variation in candle-power per month of .9 per cent. of the total light.

The results recorded in the paper were obtained with bare flames. There is no mention of a screen in the paper. In fact, the discussion has curiously turned on to the photometric

standard. The paper was not intended to bring forward a photometric standard, but merely to put on record the reliability and photometric value of different flames, with a view of ascertaining the work of others along the same line.

Now, with regard to broken chimneys, we do not break a chimney once a month. The breaking of chimneys must be due to the flame getting very much incrusted or to the use of a poor grade of oil. There are some kerosene oils in the market that are much colored and these should not be used. We have been very successful in getting the oil companies to make an oil that is nearly water white. The records of the different men who are using the lamps are very concordant, and we have not had much trouble from the breaking of chimneys.

With regard to the Hefner lamp and the pentane lamp I may say that I agree with Mr. Bond that the Hefner lamp gives too small a unit of light. Unless extra care is taken it is difficult to read to 0.10 candle with a Hefner lamp. The smallness is one objection. Another objection is its color. When white light, like that of the Welsbach is to be measured, it is troublesome to match the two shadows on the disk.

With regard to the pentane, first, it is a large clumsy instrument, and second, it does not conform to the claims for it. After a lamp has been used for some days, the remaining pentane is not the same in composition as the pentane put in. Furthermore, the light does not remain constant as with the wick burner or electric standard, or even with the Hefner. It requires constant attention, and as the room and burner become hotter, one must adjust it constantly, and it causes a great deal of trouble.

The expense of the pentane lamp is enormous. One man told me it cost $30 a month to keep his photometer lamps in operation. Now he uses kerosene oil at a cost of only $2.00 per month.

I am glad that Mr. Bond brought up the 10-cp. lamp, because it gives me a chance to speak of some of the features of the 5-cp. lamp. In a certain 5-cp lamp, which started Monday, and was turned out every night and was tested only incidentally to ee how it was getting along, the change of candle-power from Monday morning to Saturday afternoon was from 5.02 to 5.08 candle-power—a variation of less than .06 candle in the week. The lamp was not touched, not even trimmed ; it was lighted

every day, and it was allowed to burn for seven or eight hours a day. It was blown out at night and the next morning turned up and lighted with a match carefully, not to disturb the crust, and at the end of a week it had gained 0.06 candle. It is a good standard for a normal, working condition, and we are pleased with it and like it better than the ten-candle standard. The whole flame shows under test between twelve and thirteen candles, which does not drop to less than twelve candles in a week. The screen cuts 5-cp out of such a flame.

With regard to asbestos wick, that is an ingenious idea and may work. I tried another kind of a wick some time ago, a felt wick. This wick gets clogged more readily than the cotton wick. The cotton wick has a certain size and weight, like the wick of a candle, and one must be careful with it; in the original specification for the lamp the weight of the wick and the amount of material in it is mentioned. The makers take care of these details. Of course, the wick must be uniform. One size of wick cannot be used one week, and another size the next week, but they must be uniform. After a person becomes accustomed to a certain set of wicks, it does not matter much what kind of material the wick is made of.

I think the asbestos wick would be very good if it was made sufficiently loose and fluffy. The cotton wicks become tanned and get hard at the lower end and they must be thrown away. It is a good plan to abandon a wick at the end of a week, in order to prevent any change in the standard.

Mr. Elliott asked whether the change of candle-power is due to the variation in the intrinsic brilliancy or to a change in the height of the flame. It is due to change in the height of the flame. The flame does decrease a little at the end of a week, or even at the end of eight or ten hours, when it does not drop more than a quarter of an inch in height, perhaps only an eighth. A mark is provided on the steel screen, and the flame is kept to about that level. It is not essential to adjust the height accurately, however. It is not necessary to standardize every day if one obtains a good flame, a thick flame that covers the slot, and if it has a definite height to start from. It can be blown out and relighted every day, and I think it is fair to say that it will not change more than 0.1 candle in a week. That is the statement

of the men who have used it. Personally, I have not done any work with it lately, but they claim that lamp is good for a week at five candles. The candle-power at the works checks up with the candle-power at the testing stations using candles, and shows the lamp to be working pretty close to standard. The advantage of the smaller unit is obvious.

STREET LIGHTING: FIXTURES AND ILLUMINANTS.[1]

BY H. THURSTON OWENS.

"The Street Lamppost is certainly a prominent object, but as a matter of fact nobody cares what its appearance is like, except perhaps the select few who devote the greater part of their time to grumbling in general." Norton H. Humphreys, London, 1894.

In the majority of cases the above statement illustrates the conditions in this country today and, strange to say, the indifference is found among engineers as well as laymen; in fact, the former have denied having any interest in either the appearance or the type of illuminant, stating that even illumination was the chief desideratum in street lighting. My view of the matter is that the illuminating engineer is the one preeminently qualified to insure that these very matters are properly taken care of. Fortunately there is a growing popular interest in the subject, and the importance of having fixtures and illuminants which are uniform is apparent to everyone who has investigated the matter.

In the larger cities of this country, the class of street lighting may be divided into five distinct groups and each must be handled along separate lines, as follows:

1. Retail business districts.
2. Wholesale business districts.
3. Residence streets in residence districts.
4. Prominent thoroughfares in residence districts.
5. Outlying country roads.

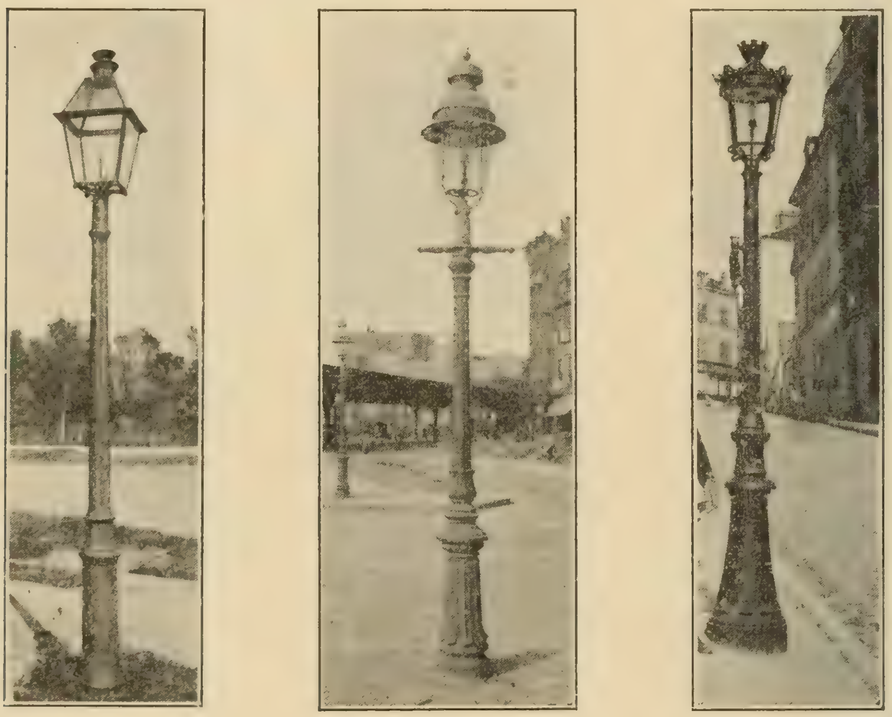
The illuminants which are available for this purpose at the present time are of three types—Electric arcs, electric incandescent and mantle lamps, gas or naphtha (only those used for regular public lighting being considered) and their development has been briefly as follows:

Gas and Naphtha Lamps: The oldest and most numerous are the gas lamps, and the open-flame type, equipped with square lanterns shown in Fig. 1 was until recently that in general use.

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

These have been gradually superseded by the mantle type, shown in Fig. 2, and this has become the standard gas lamp for the lighting of residence streets. Mantle naphtha lamps are equal to those of the gas type in efficiency and have the great advantage of being self-contained units. The mantle gas lamp used in Paris and Brussels is illustrated in Fig. 3.

Incandescent Lamps: The only other small unit which we may consider is the incandescent electric lamp, and up to the present time it has been the equivalent of the open flame gas lamp



Figs. 1, 2 and 3.—Types of Gas Lamps.

rather than the mantle type, but the fixture used has not been a credit to either the industry or the municipality. Now that more efficient types of lamps are becoming available, we may hope to see them used upon fixtures similar to those shown in Figs. 2 and 3, and *located upon alternate sides of the street.*

Arc Lamps: The well known open arc lamp has been replaced by the enclosed type to a greater extent than open flame gas lamps have been replaced by those of the mantle type, but without the great gain in efficiency. As far as the majority of installa-

tions are concerned, its appearance is greatly against it, as will be seen by referring to Fig. 4. This type, which is known as the "Mast Arm," has seen many variations, the idea being to bring the lamp well over the street and beyond the trees. Probably the handsomest post so far designed for this purpose is shown in Fig. 5, being installed along a boulevard lined with immense elms.

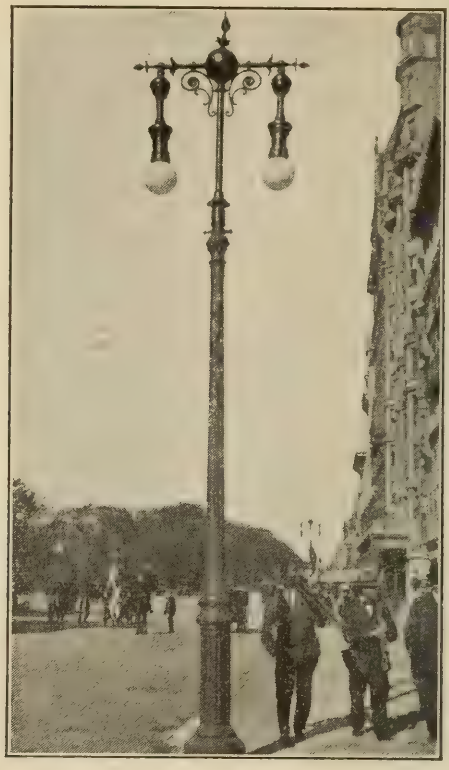
In the business portions of American cities trees are rarely to be found and the necessity of these long arms disappears, although there is a large number of lamps in use similar to the one shown in Fig. 6. This post could well be combined with the trol-

Figs. 4, 5 and 6.—Types of Electric Arc Lamps.

ley pole, also illustrated, thereby improving not only the appearance but the results as well. Unless arc lamps are equipped with dense opal globes and hung at least twenty feet high, they should not be located more than three feet beyond the curb line.

Ornamental Lighting: Street lighting installations should aim to be ornamental, but as this term is now generally used it refers more often to a spectacular installation, and many of these are now to be found somewhat similar to the incandescent lamps with frosted enclosing globes, also illustrated in Fig. 7. For this type of lamp, gas is the illuminant used in Europe; while more efficient, it is not likely to become popular here, owing to the attitude of the gas interests toward this feature of the busi-

ness. Arc lamps in pairs with dense opal globes are very effective for ornamental lighting, as the white color is in very pleasing contrast to the yellow from the incandescents upon the sur-



Figs. 7 and 8.—Ornamental Street Lamps.

rounding advertising signs. One of the older installations of this type is shown in Fig. 8.

SUMMARY

The lighting arrangements for the various districts with the illuminants at hand may be summed up as follows:

1. *Retail Business Districts*: In the retail business districts overhead trolleys are usually to be found, and in order that there may be no unnecessary duplication of poles and that the appearance of those in use may be materially improved, a combination trolley and light pole should be used. Another advantage of this system is that there will be a sufficient number of poles at hand ready for use should it be found desirable to increase the number of lamps. Where the underground trolley system has been in-

stalled, the types of lamps which can be used successfully vary greatly and the type is usually determined by the expense involved. The lamps should be hung from fifteen to twenty feet above the street and should be equipped with frosted or dense opal globes, and when so equipped, have a maximum candle power of not over 400. The larger the candle power the higher up it should be placed.

2. *Wholesale Business Districts*: Arc lamps will be found the most satisfactory for lighting these districts for two reasons, one being that heavy trucking makes it essential that the posts be as few in number as possible and, therefore, large units must be used; and the other is that the excellent reflection obtained from business buildings greatly aids the distribution.

3. *Residence Streets*: The unit should not be larger than 60 c. p., placed upon posts and not more than twelve feet above the sidewalk, and located upon alternate sides of the street. This means that mantle gas, mantle naphtha, or electric incandescent can be used.

4. *Prominent Thoroughfares in Residence Districts*: Arc lamps should be placed upon street intersections at alternate corners and not more than 300 feet apart. In case these streets are lined with trees, posts should be of the mast-arm type, the arm being long enough to bring the lamp beyond the line of the trees; and, if the traffic is very heavy, additional light should be furnished by means of additional arc lamps, or by small units. The type of lamp to be used for this additional lighting can only be determined by each individual case, but as a rule the small unit for local lighting makes the most satisfactory combination.

5. *Outlying Districts*: Owing to the expense entailed it is impossible to obtain uniform illumination upon outlying thoroughfares. Therefore, it does not greatly matter which type of lamp is selected, provided it is placed on alternate sides of the street. The selection of the illuminant here will depend greatly upon the additional commercial business which may be obtained, which is the principal reason why arcs are so often used for this purpose, not their superiority.

The question of breakage is often brought up as an argument against costly street lighting fixtures, but as a matter of fact,

as the appearance improves, willful destruction decreases; and the respect for handsome fixtures will be enhanced if their use for other purposes such as advertising, be prohibited. The architect's designs of lampposts, such as those used to adorn the entrances of buildings, cannot be taken as models for street lighting; those who contend that art commissions have the ability to cope with the matter would do well to investigate installations having their stamp of approval. Undoubtedly, therefore, it is the business of the illuminating engineer to see that the designs are dignified and artistic as well as efficient.

DISCUSSION.

Mr. C. W. Hare:—In presenting his paper the author said that a certain lighting scheme is very good, and the reason it does not work in one place is because the gas interests are against it. If we work on such lines as these we will never get anywhere. I wish to say that I am here to work in the interest of illumination, both gas and electric. It seems to me that if we can realize the principle that it is not electricity, that it is not gas, we want to push to the front, but it is the proper illumination of our cities, we will perhaps eventually reach that standard set so well before us by the work on the other side of the water. However, I am willing to state that gas as an illuminant for street lighting in this country has not been brought up to the proper efficiency. I have been informed by certain friends of mine who have spent the last two or three months in traveling through European cities, that gas is used there to a most remarkably large extent in street lighting.

Mr. C. O. Bond:—Last year Dr. Bell presented a paper showing the reflecting efficiency of different colored surfaces. It occurs to me that if the buildings along our streets were of very light color, a marvelously increased efficiency would be obtained in street lighting without changing the number of units now employed, I do not mean to advocate rebuilding the houses, but in looking to the future it is possible that commissions may exercise some control over color schemes, and keep this point in mind.

Dr. Bell said that a cream white color, reflects about sixty-four per cent. of the light delivered to it, whereas a dark

green or a dark red reflects about six per cent. The ratio is ten to one, and represents a gain certainly worth utilizing. The at present largely useless half of the illumination which is thrown on the buildings should be sent back into the streets.

The purpose of street lighting is to illuminate the surface of the street, but under the present conditions fifty per cent. of the light goes over the fence into the yard of a man who does not pay for it.

In the majority of cases we are blinded and hindered by the street light, instead of helped by it, especially in the very high units which are placed high and are inefficient. An extreme case exists in the Girard College grounds in the City of Philadelphia, where clusters of arc lamps are placed on towers 120 feet high; they are completely above the ordinary line of vision, and give the impression of a full moon. The cost of illuminating the upper air must be enormous. It might be well to lower the lamps and use proper reflectors for directing the light.

Mr. V. R. Lansingh:—With the ordinary square lamp post used for gas, one of the most suitable arrangements I have seen is one in which the panes are made of opal glass, leaving the other three clear. That scheme is employed on one of the London Bridges. The result is that the light toward the water does not glare into the eyes of the boatmen passing up and down the river, and they can see the arches of the bridge. Moreover, with the pane of opal glass, a very considerable percentage of the light is thrown back on the roadway of the bridge. By this simple expedient the useful illumination is increased by possibly 25 per cent., and danger from accident due to the glare of the light in the boatman's eyes is eliminated.

The above scheme could be adopted in our cities in order to prevent the waste of light which is going towards vacant lots or towards houses, and which makes it so uncomfortable for persons sitting on their front porches. There are other means of accomplishing this same purpose. It can be accomplished by designing globes of such a form and shape as not only to cut off the light from the house steps or the vacant lots to a considerable extent, but also to throw the light up and down the street where it is most needed. Almost all forms of street lighting in use today give a uniform horizontal distribution, so

that as much light is thrown in one direction as in the other. This subject has been almost entirely neglected. Great attention has been paid to throwing the light below the horizontal, but little to the non-uniformity of horizontal distribution. The illuminating engineer should see that the light is thrown up and down the street and not directly across the street or into vacant lots.

In the City of Washington, a great deal of difficulty was encountered with the ordinary clear lantern there in avoiding breakage, due to the throwing of stones at the lanterns by small boys. When a change was made to a boulevard type of lantern, the difficulty almost vanished, probably due to the fact that the small boy thought it was more expensive and considered that there was more danger of his being caught if he broke one of the boulevard type of lanterns.

Mr. Robert McCreery:—The best examples of ornamental street lighting fixtures I have seen are those on Atlantic Avenue at Atlantic City, where clusters of tungsten lamps are used. There are four clusters on each side of the street, with four in a cluster, about 20 feet high. At the corner of the intersecting streets use is made of a much higher pole with an arc lamp on top, and eight tungsten lamps on each side of the pole. These lamps illuminate the streets in a most excellent manner.

Mr. J. E. Woodwell:—Mr. Owens mentioned the use of opal shades on street lamps. I think that it is necessary to cut down the intrinsic brightness of the light sources, but inadvisable to project the light up and down the street. It is more desirable to place a larger number of units on the street, and to direct the light more in a downward direction, so as to relieve the visual strain occasioned by an intensely bright light source in the field of view.

Those who have seen the lighting of the Connecticut Avenue bridge at Washington will bear me out in the statement that it is an example of successful street lighting, inasmuch as the roadway is fairly uniformly lighted and the sources are of very low intrinsic brightness. In this particular instance use is made of Nernst lamps, which of course give a strong downward distribution of light, and the globes are of dense opal glass, which reduces the intrinsic brightness to a very low value, perhaps lower than heretofore attempted. The result, in my opinion, is

eminently successful and indicates what can be accomplished by that particular method.

President Bell:—The Chair may incidentally remark that the Nernst lamps used abroad, which are not very numerous, but are found freely in certain localities, are usually of the comparatively early type with the vertical glower. The result, of course, is an illumination which is very largely in a horizontal direction.

R. S. Hale:—(By letter). In Vienna in the public parks

Vienna Lamp Post.

and in the Ringstrasse which is more or less of a park, the city has provided some very handsome lamp poles. These differ from any in use in America, being much higher than those employed here for arc lamps. The lamps are placed from 10 to 12 meters from the ground, thereby affording a much better illumination.

These poles are of Muesmann rolled steel and are provided with a flower box about half way up, which is filled from time to time with flowers just like a window box, the effect being very beautiful, as noted in the accompanying illustration.

The Boston Edison Company has just ordered two of these

poles with flower boxes, for installation in one of the Boston parks.

Mr. H. Thurston Owens:—I can answer Mr. Hare's remarks regarding the position of the gas interests in this country by stating that the mantle gas lamp has the field today for residence street lighting, but not for the ornamental lighting. If there are any ornamental street lamps in which gas is the illuminant, I should like very much to hear about them.

Mr. Bond's remarks about the colors of the house are very true. In Paris, where excellent reflection is obtained from the gray and white buildings most of which are of concrete, the results are better than in America.

Mr. Lansingh's remarks regarding the small boy are very true. As stated in the paper, as the appearance improves, the wilful destruction decreases rapidly—more so than is generally realized.

In reply to the written discussion from Mr. Hale, I may say that any ornamental installations should be welcomed, but the tendency abroad of placing lamps from 33 to 39 feet high such as the ones mentioned is a step in the wrong direction. A height of 20 feet for regular lighting, and 25 feet for special poles in large squares, seems to be about the maximum unless the desire is to illuminate the heavens.

THE RELATION BETWEEN CANDLE-POWER AND VOLTAGE OF DIFFERENT TYPES OF INCANDESCENT LAMPS[1]

BY F. E. CADY.

One of the most important relations governing incandescent lamps is that between voltage and candle-power. In the early days of poor voltage regulation this was evident even to the unskilled eye. At the present time while a good system may have voltage changes large enough to have an appreciable effect on the life of lamps, they are generally too small to affect the candle-power to a noticeable extent. It is not the purpose of this paper to deal with this relation in its commercial aspect, but rather to discuss its scientific and technical purport, to study the equation which represents it, and to present an easy method of applying it in computing the changes in candle-power corresponding to different finite changes in voltage.

Early work on this subject was devoted more to a study of the relation of candle-power to watts input than to that of voltage. In 1880, the very year in which Edison's "cardboard" lamp was produced, investigations were made[2] by Prof. Rowland and by Henry Morton.[3] In the following year Sir Wm. Thomson made some rough tests[4] to determine the illuminating power of some incandescent lamps over a wide range of voltage.

The first elaborate research seems to have been made by Jamieson[5] who suggested the equation $I = \left(\frac{V}{A}\right)^6$, I being the candle-power, V the volts, and A a constant, as representing the curve of candle-power and voltage. He was followed by Dr. Voit[6] who utilized the large number of tests made at the Munich Exposition, and concluded that $I = a E^3$, E being the watts and a a constant, gave the best agreement with the

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

[2] The London *Electrician*, 4, 1880; p. 271.

[3] *Philosophical Magazine*, July 1880.

[4] British Association *Report*, 1881; p. 559.

[5] *Jour. Soc. Tel. Eng. and Electricians*, 42, 1882.

[6] *La Lumière Electrique*, X; p. 87.

data on candle-power and watts. In a paper on "The Characteristic Curves and Surfaces of Incandescent Lamps"[1], Dr. Fleming states that the candle-power varies as the sixth power of the voltage. Palaz, in his "Industrial Photometry" p. 212, concludes that the luminous intensity of an incandescent lamp is given by the sum of two terms, one of which is proportional to the watts consumed in the lamp, and the other to the third power of this value of watts.

Ferguson and Centre[2] give the equations $I = a\,E^3$, $I = b\,V^{6.6}$. Ayrton and Medley[3] give $I = a\,E^{2.9}$, and $I = b\,V^{5.91}$ as the results of tests on some 8-cp. lamps which had been in use for from 200 to 300 hours. In his "Photometrical Measurements", p. 181, Prof. Stine comments on the apparent disagreement of filaments under any one set of conditions, and ascribes this to the physical nature of the carbon.

All of the above references concern carbon-filament incandescent lamps, but, in general, information as to whether the filaments were treated or untreated is lacking.

The introduction of the new type of metallic filament lamp and the effort to compare its efficiency and life with that of the carbon lamp has brought up again the question of the relation of candle-power to voltage and watts. Prof. Lombardi published some data[4] showing the change in candle-power and watts with change in voltage, of two osmium lamps. Blau[5] found for a carbon lamp an 80 per cent. increase in candle-power for a ten per cent. increase in voltage. For an osmium lamp at 1.88 watts per mean spherical candle he found 40 per cent. increase in candle-power for 10 per cent. increase in voltage. From these data there would be for the carbon lamp $I \propto V^{6.2}$, and for the osmium lamp $I \propto V^{3.5}$. In some tests on tantalum lamps by Prof. Ambler,[6] the results for a carbon lamp at 3.76 watts per mean spherical candle gave $I \propto V^{5.5}$, and for a tantalum lamp at 2.1 watts per mean spherical candle, $I \propto V^{2.2}$. Data have been published also by Dr. Sharp[7] and by Dr. Fleming, J. T. Morris

[1] The London *Electrician*, 14, 1885; p. 418.
[2] *Technology Quarterly*, 1891; p. 147.
[3] *Philosophical Magazine*, 39, 1895; p. 421.
[4] *Electrotechnische Zeitschrift*, 25, 1904, p. 41.
[5] The London *Electrician*, 54, 1905; p. 799.
[6] The London *Electrician*, 55, 1905 p. 941.
[7] The London *Electrician*, 58, 1907; p. 602.

and Prof. Kapp.[1] In *Bulletin* No. 19, of the University of Illinois, T. H. Amrine, gives some results on a carbon, a graphitized and a tantalum lamp.

In nearly all of the above cases the specific consumption at which the lamps were operating when the data for the exponents were obtained is not stated, and for reasons which will appear later, it is not possible to compare the results adequately. In a paper on the effect of change of voltage on the candle-power of glow lamps[2] by F. Hirschauer, values of the exponent are given for a number of different types of lamps. The author, however, draws some conclusions directly at variance with those of this paper, and moreover, the data as in most of the other published experiments, are not sufficiently complete to warrant comparison.

As noted above, the candle-power voltage and candle-power wattage relations are ordinarily expressed by equations of the form $I = aV^k$ and $I = a'E^{k'}$, where I is the candle-power, V the voltage, E the watts, and a, a', k, k' are constants. The values of the constants have usually been obtained from curves made by finding the candle-power and watts corresponding to successive voltages. Knowing these constants, the candle-power at any voltage, or wattage, may be calculated.

If two lamps have the same candle-power at different voltages, k being the same, the value of a will be different in the two cases. If used, therefore, a must be determined for every individual lamp. This would obviously be a laborious process. To evaluate a the candle-power must be measured at two or more voltages. If, however, the candle-power of a lamp is known at one voltage, its candle-power may be calculated at another voltage, provided one knows how much change in candle-power is produced by the given change in voltage.

The percentage change in candle-power when the voltage is changed by one or more per cent. depends upon the value of k. If the percentage change in voltage is small enough, the percentage change in candle-power can be taken as k times the percentage change in voltage. Thus taking the derivative of the equation $I = aV^k$, we have

[1] The London *Electrician*, 58, 1907; 523.

[2] *Electrotechnische Zeitschrift*, January 30, 1908.

$$dI = akV^{k-1}dV.$$

Dividing by $I = aV^k$

$$\frac{dI}{I} = k\frac{dV}{V},$$

or the percentage candle-power change, $\frac{dI}{I}$, corresponding to an infinitesimal voltage change, dV, is k times the percentage change in voltage $\frac{dV}{V}$. The exponent k will be called the infinitesimal coefficient, since the percentage change in candle-power is obtained by multiplyiug the percentage change in voltage by the coefficient k when the change in voltage is small. As the change in voltage becomes larger, the exponent k can no longer be employed as a coefficient, the error increasing as the change in voltage becomes greater and greater.

If the value of the exponent k is known over the range of voltage to be employed, of course the candle-power at any other voltage can be computed from the candle-power at any given voltage by direct application of the characteristic equation $I = aV^k$. Thus if at voltage V_o the candle-power is I_o, the value of I_x at any other voltage V_x is seen at once to be $I_x = \left(\frac{V_x}{V_o}\right)^k I_o$. Inasmuch as this equation, involving the use of logarithms, is frequently not as convenient to use as a simple coefficient, the following method has been employed to determine for any finite voltage change, a finite coefficient K, which, when multiplied by the finite percentage change in voltage $\frac{V_x - V_o}{V_o}$ gives the percentage change in candle-power $\frac{I_x - I_o}{I_o}$. According to this definition

$$K = \frac{\frac{I_x - I_o}{I_o}}{\frac{V_x - V_o}{V_o}} = \frac{\left(\frac{I_x}{I_o}\right) - 1}{\left(\frac{V_x}{V_o}\right) - 1} = \frac{\left(\frac{V_x}{V_o}\right)^k - 1}{\left(\frac{V_x}{V_o}\right) - 1} = \frac{\gamma^k - 1}{\gamma - 1},$$

where $\gamma = \frac{V_x}{V_o}$. The value of K depends both on k and on the ratio of the voltages γ.

In other words there is now obtained a relation such that if the infinitesimal coefficient is known one can find the change in candle-power for any finite change in voltage over which the value of k holds. Or conversely, if the change in candle-power produced by a given finite change in voltage is known one can determine the infinitesimal coefficient which holds over that range.

Assign to k the values 1, 2, 3, 4, etc. and for each value of k take a succession of values of $\frac{V_x}{V_o}$ and calculate K. The result

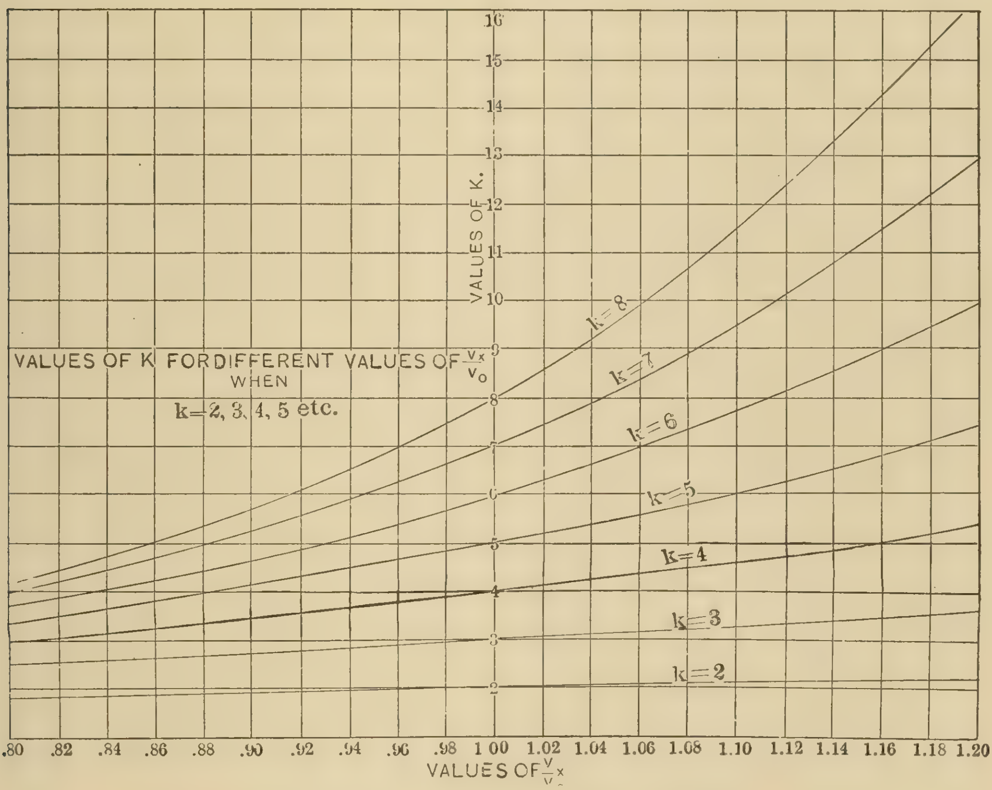


Fig. 1.—Values for K for Different Values of $V_x \div V_o$.

will be a series of values of K corresponding to each given value of k, and these can be plotted in the form of a curve with values of $\frac{V_x}{V_o}$ as abscissae, and values of K as ordinates. There will be a separate curve for each k, and in each case where $\frac{V_x}{V_o} = 1$, $K = k$. Fig. 1 shows such a series of curves for different values of k from $k = 1$ to $k = 8$ where $\frac{V_x}{V_o}$ varies from 0.80 to 1.20, and Table 1 gives the data from which the curves were plotted.

TABLE I—VALUES OF K FOR DIFFERENT VALUES OF $\frac{V_x}{V_o}$

WHEN $k = 2, 3, 4$, ETC.

	$k = 2$	$k = 3$	$k = 4$	$k = 5$	$k = 6$	$k = 7$	$k = 8$
0.80	1.800	2.440	2.952	3.362	3.689	3.951	4.161
0.81	1.810	2.466	2.998	3.428	3.777	4.059	4.288
0.82	1.820	2.492	3.044	3.496	3.867	4.171	4.420
0.83	1.830	2.519	3.091	3.565	3.959	4.286	4.558
0.84	1.840	2.546	3.138	3.636	4.054	4.406	4.701
0.85	1.850	2.572	3.187	3.709	4.152	4.530	4.850
0.86	1.860	2.600	3.236	3.783	4.253	4.658	5.006
0.87	1.870	2.627	3.285	3.853	4.357	4.790	5.168
0.88	1.880	2.654	3.336	3.936	4.463	4.928	5.336
0.89	1.890	2.682	3.387	4.014	4.573	5.070	5.512
0.90	1.900	2.710	3.439	4.095	4.686	5.217	5.695
0.91	1.910	2.738	3.492	4.177	4.801	5.369	5.886
0.92	1.920	2.766	3.545	4.262	4.921	5.527	6.085
0.93	1.930	2.795	3.599	4.347	5.043	5.690	6.292
0.94	1.940	2.824	3.654	4.435	5.169	5.859	6.507
0.95	1.950	2.852	3.710	4.524	5.298	6.033	6.732
0.96	1.960	2.882	3.766	4.616	5.431	6.214	6.965
0.97	1.970	2.911	3.824	4.709	5.568	6.400	7.208
0.98	1.980	2.940	3.882	4.804	5.708	6.594	7.462
0.99	1.990	2.970	3.940	4.901	5.852	6.794	7.726
1.00	2.000	3.000	4.000	5.000	6.000	7.000	8.000
1.01	2.010	3.030	4.060	5.101	6.152	7.214	8.286
1.02	2.020	3.060	4.121	5.203	6.307	7.433	8.582
1.03	2.030	3.091	4.184	5.310	6.469	7.663	8.893
1.04	2.040	3.122	4.247	5.417	6.634	7.899	9.215
1.05	2.050	3.152	4.310	5.526	6.802	8.142	9.549
1.06	2.060	3.184	4.375	5.637	6.975	8.394	9.898
1.07	2.070	3.215	4.440	5.751	7.153	8.654	10.260
1.08	2.080	3.246	4.506	5.866	7.335	8.922	10.636
1.09	2.090	3.278	4.573	5.985	7.524	9.201	11.029
1.10	2.100	3.310	4.641	6.105	7.715	9.486	11.435
1.11	2.110	3.342	4.710	6.228	7.913	9.783	11.859
1.12	2.120	3.374	4.779	6.353	8.115	10.089	12.300
1.13	2.130	3.407	4.850	6.480	8.322	10.464	12.757
1.14	2.140	3.440	4.921	6.610	8.535	10.730	13.232
1.15	2.150	3.473	4.994	6.743	8.754	11.067	13.727
1.16	2.160	3.506	5.067	6.878	8.978	11.414	14.240
1.17	2.170	3.539	5.141	7.015	9.208	11.773	14.774
1.18	2.180	3.572	5.215	7.154	9.442	12.142	15.327
1.19	2.190	3.606	5.291	7.296	9.682	12.522	15.901
1.20	2.200	3.640	5.368	7.442	9.930	12.916	16.499

The above curves have been worked out on the assumption that k is a constant. It is well to examine one or two cases where k is not a constant, and see what errors would arise if over a definite range of values of $\frac{V_x}{V_o}$ use is made of the average value of k. As an illustration assume that $k = 4$ for the interval from $\frac{V_x}{V_o} = 1$ to $\frac{V_x}{V_o} = 1.01$; that $k = 4.1$ for the interval 1.01 to 1.02; $k = 4.2$ from 1.02 to 1.03, etc. up to $\frac{V_x}{V_o} = 1.10$ when $I_x = I_{10}$. If now I_{10} be calculated by getting I_1 from I_0, I_2 from I_1, I_3 from I_2, etc., using in each case the corresponding values of k, the same value is obtained to within a negligible error as would be found if I_{10} were calculated from I_0 directly, using for k the average of the values from $k = 4$ to $k = 4.9$ inclusive. The same result is obtained when the case where k is made to vary by small irregular increments or decrements is selected.

The curves as given are calculated for integral values of k. It is possible to determine them for any intermediate values, but for photometric work sufficient accuracy may be obtained by interpolation when the value of k lies between two of those given.

In order to illustrate the practical use of the above curves, take as an example, the candle-power of a tungsten lamp known to be 40 at 110 volts, and find its candle-power at 121 volts when its infinitesimal coefficient for this range is 3.5. Here $\frac{V_x}{V_o} = 1.10$. From the plot for $k = 3$, $K = 3.28$; for $k = 4$, $K = 4.62$, therefore for $k = 3.5$, $K = 3.95$. Therefore the percentage change in candle-power is 10x3.95 or 39.5 per cent. Therefore the candle-power at 121 volts will be $40(1 + .395) = 55.8$.

If the candle-power is known at two voltages, the value of K will be the percentage change in candle-power divided by the percentage change in voltage. The value of k may then be determined from the table or the curves either directly or by interpolation. In a recent article[1] by M. H. Pecheux, values of k are given, together with the data from which they were obtained, for a carbon, a tantalum, and a tungsten lamp. The

[1] *La Lumière Electrique*, May 16, 1908.

values of k derived by the above method, using these data, agree exactly with those obtained by M. Pecheux.

A study of previous work where values of k have been deduced shows considerable variation with different observers, even with the same types of lamps. These variations may have been due to the methods used in obtaining the coefficient, to actual differences in the lamps themselves in the early stages of their manufacture, or to the fact that the coefficient is not a constant but a function of the specific consumption, that is, the watts per mean spherical candle.

An investigation recently carried on at the Bureau of Standards with another purpose in view furnishes evidence on this point. This investigation has not yet been completed, but the data so far obtained are sufficient to show that k is not a constant, and to indicate that k is a function of the specific consumption. These data are given in Table II. In column I are recorded the types of filament. Column 2 shows the individual lamps of each kind tested. Above each of the remaining columns are specified the watts per mean spherical candle at which measurements were made, and beneath are shown the values of k derived from these measurements.

TABLE II—VALUES OF k FOR VARIOUS LAMPS AT DIFFERENT WATTS PER MEAN SPHERICAL CANDLE

Type of filament	Lamp No.		Values of k			
			33 w.p.c.	8.6 w.p.c.	3.6 w.p.c.	
Untreated Carbon	1		8.0	7.0	6.5	
	2		8.0	7.1	6.3	
	3		8.1	7.0	6.4	
	4		8.0	7.1	6.4	
		mean	8.02	7.05	6.40	
			31 w.p.c.	8.0 w.p.c.	3.5 w.p.c.	1.9 w.p.c.
Treated Carbon	1		6.9	6.0	5.4	
	2		6.9	5.9	5.2	
	3		7.0	6.1	5.4	
	4		6.9	5.85	5.4	5.0
	5		7.0	6.0	5.6	5.0
		mean	6.94	5.97	5.40	5.00
			31 w.p.c.	8.3 w.p.c.	3.5 w.p.c.	
Gem	1		6.1	5.4	4.9	
	2		6.2	5.5	4.9	
	3		6.0	5.2	4.9	
	4		6.1	5.3	4.9	
		mean	6.10	5.35	4.90	

TABLE II.—(*Continued*).

Type of filament	Lamp No.		Values of k				
			33 w.p.c.	8.6 w.p.c.	3.6 w.p.c.		
			26 w.p.c	7.4 w.p.c.	3.3 w.p.c.	1.7 w.p.c.	
Tantalum	1		5.2	4.6	4.3		
	2		5.1	4.4	4.2		
	3		5.1	4.6	4.2		
	4		5.1	4.4	4.0		
	5		5.0	4.5	4.1	3.8	
	6		5.0	4.5	4.1	4.0	
		mean	5.10	4.50	4.15	3.9	
			18 w.p.c	5.5 w.p.c.	2.6 w.p.c.		
Osmium	1		4.7	4.2			
	2		4.7	4.1	3.9		
		mean	4.7	4.15	3.9		
			22 w.p.c.	6.3 w.p.c.	2.9 w.p.c.	1.6 w.p.c.	1.3 w.p.c.
Tungsten	1		4.5	4.1	3.9		
	2		4.6	4.0	3.8	3.7	
	3		4.6	4.2	3.8	3.6	
	4			4.2		3.7	3.5
	5			4.2		3.6	3.4
	6			4.1		3.6	3.5
		mean	4.57	4.13	3.83	3.64	3.47

It will be noticed that measurements of different types were not made at exactly the same watts per mean spherical candle, and that there is a large interval between the first and second specific consumptions. Furthermore, values are not given for every lamp at each specific consumption. All of these deficiencies are due to the fact above mentioned that the data are taken from a research which has been carried on for another purpose. Nevertheless the data are sufficient to permit of quite definite conclusions as to the relations between k and the specific consumption.

A study of this table shows first that lamps of the same kind have the same infinitesimal coefficient k when operated at the same watts per mean spherical candle. Secondly, that the infinitesimal coefficient decreases as the watts per mean spherical candle decrease. Thirdly, the change in the coefficient is not large for a considerable change in specific consumption, of which the slope of the curves shown later is evidence. Fourthly, at approximately the same watts per mean spherical candle the coefficient

is different for lamps of different kinds of filament, decreasing from low-efficiency lamps to those of higher efficiency. These facts may be seen also by examining of Fig, 2. which is a plot of the mean values given in Table II.

It it evidently possible to determine with fair accuracy the value of k corresponding to any desired watts per mean spherical candle within the range, even though the points lie comparatively far apart, for the reason that the slope of the curves is so slight. Thus the values of k for the different types at the watts per mean horizontal candle at which they are ordinarily used have been derived by interpolation and are given in Table III. The corresponding watts per mean spherical candle are given in the third column. They were derived from the values in column 2,

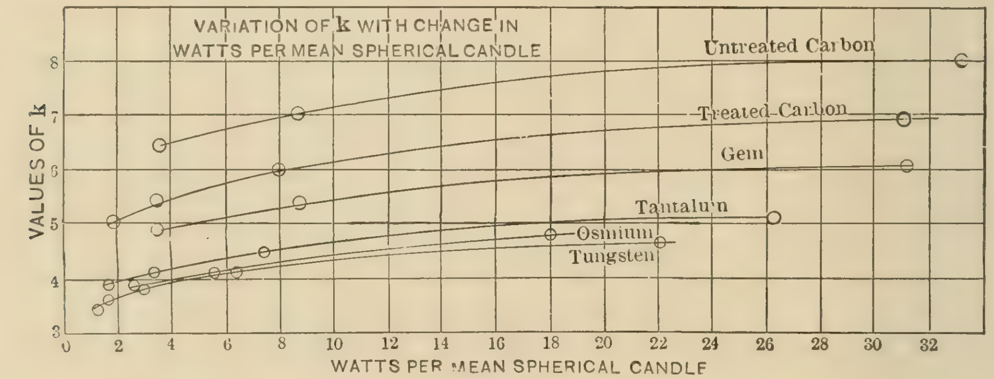


Fig. 2.—Variation of k with Change in Specific Consumption.

by assuming reduction factors of 0.825 for the carbon and 0.80 for the other lamps.

TABLE III—VALUES OF k FOR DIFFERENT FILAMENTS AT ORDINARY SPECIFIC CONSUMPTION

Type of Filament	Watts per Mean Horizontal Candle	Watts per Mean Spherical Candle	k.
Untreated Carbon	4.0	4.85	6.6
Treated Carbon	3.1	3.76	5.4
Gem	2.5	3.12	4.8
Tantalum	2.0	2.5	4.0
Osmium	1.5	1.85	3.8
Tungsten	1.25	1.56	3.6

The values obtained by M. Péchaux[16] for the tantalum lamp, that is $k = 3.9$ at approximately 1.8 watts per mean spherical candle ; and for the tungsten lamp, $k = 3.4$ at approximately 1.2 watts

[16] *Loc. cit.*

per mean spherical candle agree very well with the values given in Table II.

In order to further test the constancy of k for lamps of the same kind of filament when at the same specific consumption, a number of tungsten lamps of different makes were photometered with this end in view. The results are given in Table IV. To the above results have been appended values deduced from data previously obtained at different times on other tungsten lamps.

TABLE IV - VALUES OF k FOR DIFFERENT TUNGSTEN LAMPS AT APPROXIMATELY 1.56 WATTS PER MEAN SPHERICAL CANDLE

Type	Lamp No.	k.
Just	1	3.7
	2	3.6
	3	3.7
	4	3.6
	5	3.6
	6	3.7*
Sirius Colloid	1	3.6
	2	3.6
	3	3.6
	4	3.6
	5	3.6
	6	3.5*
	7	3.6*
	8	3.5*
General Electric	1	3.6
	2	3.6
	3	3.7
	4	3.6
Columbia	1	3.6
	2	3.6
Kuzel	1	3.7*
	2	3.8*
	3	3.7*

Values marked * were taken from data not obtained for this special purpose.

It may be said in reference to the slight differences that appear, that it is necessary in making an accurate determination of k to observe the candle-power readings with the greatest care; it is evident that if the range in candle-power is, say, only 10 or 15 per cent., a slight error in reading the candle-power at either voltage will make a relatively large error in k. For instance, if

the range in candle-power is 10 per cent., an error of only 0.5 per cent. in one candle-power reading will make a 5 per cent. error in k.

A method for determining k, through the percentage change in candle-power produced by a given percentage change in voltage, which has given very satisfactory results is as follows: Choose a range of voltage which will give from 30 to 40 per cent. change in candle-power. Measure the candle-power successively at the lower voltage, then at the higher voltage, at the lower voltage again, at the higher, and finally again at the lower. This gives five sets of candle-power readings. The difference between the second set and the mean of the first and third sets, divided by the mean of the first and third sets, gives one value of percentage candle-power change. The difference between the fourth set and the mean of the third and fifth sets, divided by the mean of

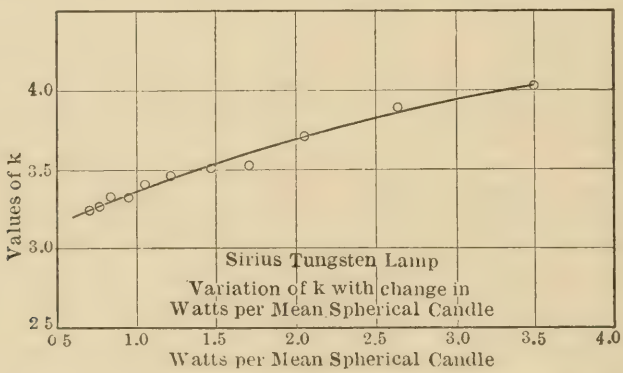


Fig. 3.—Variation of k with Change in Specific Consumption.

the third and fifth sets, gives another value of the percentage candle-power change. The mean of the two values of percentage candle-power change is then taken as the candle-power change corresponding to the given percentage voltage change. The ratio of the percentage change in candle-power to the percentage change in voltage is the finite coefficient K. The value of the infinitesimal coefficient k is then determined by the method outlined in a previous paragraph.

Figure 3 shows some results on a Sirius tungsten lamp at higher watts per mean spherical candle than most of those given in Fig. 2. The slope of the curve is quite definite. Table V gives some values of k obtained with some 32 c. p. treated carbon filament lamps. These lamps were tested for another purpose, the data, however, permitting of the determination of

the value of k. As will be seen, the agreement with values calculated from Fig. 2, is very good.

TABLE V—VALUES OF k FOR SOME 32—CP CARBON LAMPS

Lamp	Watts per Mean Spherical Candle	k.	k. Calculated from Plot
1	3.9	5.5	5.4
2	3.9	5.5	5.4
3	4.0	5.5	5.5
4	3.9	5.4	5.4

While it would be highly desirable to get more of accurate data on the various types of lamps photometered, and on others, and more especially on a large number of lamps of each kind from different makers, yet it is believed that the above results establish conclusively the following facts :

That the exponent for change of candle-power with change of voltage is not a constant but a function of the watts per mean spherical candle ; that this exponent is different for different types of filament, but probably very closely the same for lamps of the same type of filament when operated at the same watts per mean spherical candle ; that the value of the exponent decreases as the watts per mean spherical candle decrease.

It follows therefore that an equation of the form $I = a V^k$ where a and k are constants does not represent accurately the data for filaments of any material. The equation must have two or more terms, and an effort should be made to find the forms and constants of the equations for various kinds of filaments.

It had been intended to incorporate in the above discussion the relation between candle-power and watts, together with a determination of the actual equations representing both this relation and that between candle-power and volts. Though lack of time prevented this, it is hoped that the work may be completed in the near future.

It may be well to note that the data of Table I may be used in the study of any phenomenon represented by an equation of the type $x = ay^b$.

The writer desires to acknowledge his indebtedness to Dr. E. P. Hyde for many valuable suggestions, and to thank him and other members of the photometric section of the Bureau of Standards for assistance in preparing this paper.

DISCUSSION.

Mr. Preston S. Millar:—I was somewhat startled in reading the paper to learn that in the case of the treated carbon-filament lamps the exponent (which when applied to the change in voltage, shows the change in candle-power) varies considerably throughout that range in volts encountered in practical photometric and lighting work.

The question at once arises—what error would be encountered if one were to adopt the best constant exponent and use it to compute variations in candle-power from that yielded by the lamp when operated at a specific consumption of 3.1 watts per mean horizontal candle-power? My impression—and I regret that at this time it is only an impression—is that the error so encountered would be very small throughout a range of from 16 to 10 candle-power, and that for all practical purposes such error would be quite negligible. In fact, it would be so small that if the test were conducted under different conditions and by using different photometers differences of equal magnitude might be encountered in experimental results.

I regret very much that the author has not seen fit to state the experimental results and the conditions and methods of test under which they were obtained. Since for approximation work throughout such a range as that indicated above it has been considered that a constant exponent might be used, the results brought out in this paper are extremely interesting and have a practical bearing which cannot well be ignored. Scientifically, they are interesting but in neglecting to state their practical application the author leaves us in the dark as to one phase of the question in which the members of this Society are particularly interested. I wish that Mr. Cady would tell us something about the conditions under which the tests were made and the magnitude of the errors which would be encountered by using the best constant exponent throughout a limited range of variation in volts.

Dr. A. S. McAllister:—The value of the exponent given in the paper has reference to the change in candle-power with the voltage, not with the watts. Now, the candle-power depends on the watts and the temperature, while the voltage which produces the watts will depend on the specific resistance of the material,

which varies with the temperature. The untreated carbon, which has the highest exponent, has a negative resistance-temperature coefficient, so that as the voltage increases the resistance of the filament decreases. The tungsten lamp, on the other hand has a low exponent; moreover, the resistance of tungsten increases with the voltage. It seems, therefore, that the change in the resistivity with the temperature must have a considerable effect on the value of the exponent. Is not the difference in the values of the exponents for the various lamps due more to the differences in the resistance-temperature coefficients than to any change in the specific consumption at which the filaments are usually operated?

Dr. Clayton H. Sharp:—Can Mr. Cady state what effect the change in the exponent has upon the values determined for the candle-power? What is the significance of a 10 per cent., 5 per cent. or a 2 per cent. change in the exponent as far as the shape of the cp.-voltage curve is concerned?

Dr. E. P. Hyde:—One very interesting result of these experiments is the uniformity in the shapes of the curves; all of them run in approximately the same way. I think it is self evident that the form of the equation will be approximately the same for the various types of lamps. The curves run approximately parallel, one with respect to the other. This fact is apparent by consulting the different sheets.

Dr. Louis Bell:—Have any curves been derived for the variation in candle-power with change in current?

Mr. Francis E. Cady:—In answer to the last question I may say that while such curves have not been derived, the data for them are available. Since the publication of this paper I have computed the coefficient for change in candle-power with change in watts. These coefficients show the same general characteristics as the ones discussed in the paper. The differences, however, between values for the different types when at the same watts per mean spherical candle are not as great as those between the coefficients for change in candle-power with change in voltage and the slope of the curves showing the change in the coefficient with change in specific consumption is not so great.

In regard to Mr. Millar's question as to how these results were obtained, I would refer to that portion of the paper which

describes in detail a method for obtaining the values of the infinitesimal coefficient with a fairly high degree of accuracy. As stated in the paper, much of the data was obtained from experiments carried on for another purpose. If the details of these experiments are desired, I shall be very glad to furnish them.

In regard to the question as to whether the change in the coefficient is not due to the change in resistance, I am not yet prepared to say what the cause of the change is. The results show that the coefficient is a function of the specific consumption, but the reason for this is another question.

In reply to the question of Mr. Millar, and repeated by Dr. Sharp, as to the error which would arise if the values of the coefficients given in the paper were used commercially, I should say that I have not been able to find any published reports of the values used either by lamp factories or by testing laboratories, or of the methods used in obtaining them. Not knowing the values used commercially, I am unable to state what error would arise if the values given in the paper were used.

I should like to emphasize the fact that it is the purpose of the paper to show the laws indicated by the results given, rather than the actual numerical values of those results. In order to determine the numerical values, measurements should be made on a large number of lamps of each type.

Mr. J. T. Marshall:—(Communicated after adjournment). The importance of a knowledge of the relation between the candle-power, volts, amperes, watts, specific consumption and life of incandescent lamps was recognized at the lamp Works of the General Electric Company at the very beginning of lamp manufacture. It was found most convenient to put the data in the form of curves, and such curves were produced as early as 1881.

The early method was to test the lamps for volts and amperes through a range of candle-power and plot the results, expressing them in terms of per cent. of the candle-power, volts, amperes, etc., at the standard specific consumption.

The candle-power and life relation was determined by ascertaining the lives of lamps from the same batch set up at different candle-powers. As long ago as 1884, the average results indicated that the life of a carbon lamp varied inversely as the 3.65 power of the candle-power. This relation has been sub-

sequently checked at intervals of several years, both with treated and untreated carbon filaments with the result that the old figure still stands. From the limited experience had with metal-filament lamps, we are inclined to believe that with them the same relation exists.

A photo-lithograph, printed March 22, 1905, shows for the treated oval carbon-filament lamp the relation between candle-power, volts, amperes, watts, specific consumption and life for from two to six watts per mean horizontal candle-power. I want to call particular attention to the fact that all of these curves were derived from formula and are parts of curves extending from 1⅓ to 19 watts per candle. Their accuracy for this particular type of lamp has been verified by comparison with the data from which they were derived, and found to hold very well throughout the whole length of the curves. I say "for this particular type of lamp" because, while the form of the equation may be applied to any type of lamp, and has actually been satisfactorily applied to produce curves for untreated carbon, "metallized" carbon, tantalum, osmium and tungsten lamps, the constants for each type are different except that the constants for the relation of candle-power and watts are very nearly the same for all types tested. Even for the treated-carbon-filament lamp, the relations of candle-power, volts and amperes will be different, depending on the relative dimensions of the core and shell, and for this reason it will be well to describe how the lamps were selected for these curves.

About 1,000 oval-filaments were selected, the average size and length being such as are used for 16 cp., 116 volts, 3.1 watts per candle lamps. These were treated and made into lamps and from these lamps there were selected twenty-five that at 16 cp. were the same in volts and nearest 3.1 watts per candle in specific consumption. Each of the twenty-five lamps was then tested for volts and amperes at seventeen different candle-powers between 1 and 64. The results were averaged, the fundamental data for the curve being obtained from the averages.

Of course, these results might have been plotted directly on cross-section paper, but it is so difficult to decide just how to draw a curve through a series of experimentally determined points that it is desirable, if possible, to obtain a formula for

the curve. In obtaining the formula, no consideration was had for its simplicity, because it was not expected to use the formula for any purpose other than to produce the curves. The curves seem to be the simplest device for recording the information required.

I now wish to show how these formulas came to be chosen and how they work out as applied to one particular lot of typical Gem lamps.

Approximately the candle-power varies as some power of the volts, amperes or watts, but only approximately, because the exponent varies in different parts of the curve. If the exponent were constant, there would be a constant difference between the successive volt-logarithms, corresponding to the successive powers of the candle-power.

It was observed that, while there was a varying difference between the successive volt-logarithms, the difference between these differences was nearly constant. It was, therefore, not unreasonable to suppose that the introduction of a third difference might make it possible to obtain a formula, which would produce a curve that would conform very closely to the experimental curve throughout its whole length. If such a formula could be obtained, it would provide a means for accurately fixing all points of the curve.

The successive candle-powers can be arranged in a series corresponding to the formula:

$$\text{Candle-power} = ab^{(n-1)}$$

a = the first term of the candle-power series,
b = the ratio between any term and its preceding term,
n = the number of the term.

The volt logarithms can be arranged in a corresponding series, according to the previously described scheme and this formula will be:

$$\text{Log. of volts} = a + b(n-1) + \frac{c}{2}(n-1)(n-2) + \frac{d}{6}(n-1)(n-2)(n-3).$$

The derivation of this formula may be illustrated as follows:
Below is a hypothetical table:

1	2	3	4	5
1	.1004	....	....	....
2	.1007	.0003	....	....
3	.1012	.0005	.0002	....
4	.1020	.0008	.0003	.0001
5	.1032	.0012	.0004	.0001
6	.1049	.0017	.0005	.0001
7	.1072	.0023	.0006	.0001

Column 1 is the number of the term in the series of logarithms.

Column 2 is the hypothetical series of logarithms.

Column 3 shows the difference between each number and its predecessor in column 2.

Column 4 shows the difference between each number and its predecessor in column 3.

Column 5 shows the difference between each number and its predecessor in column 4.

This table is arranged, with the values in column 5 as constant, so as to conform to the original hypothesis.

Let a = the first number in column 2 = .1004
Let b = the first number in column 3 = .0003
Let c = the first number in column 4 = .0002
Let d = any number in column 5 = .0001

Taking term No. 6 as an example from the table,

$$.1049 = .1004 + .0003 \times 5 + \frac{.0002}{2} 5 \times 4 + \frac{.0001}{6} 5 \times 4 \times 3$$

or,

$$.1049 = a + b(n-1) + \frac{c}{2}(n-1)(n-2) + \frac{d}{6}(n-1)(n-2)(n-3).$$

Twenty-five typical "metallized-filament" lamps were tested for volts at 1, 2, 4, 8, 16, 32, and 64 candles, and the results were averaged as follows:

Candle-power	Volts	Amperes	Watts	Watts per candle
1	56.1	.333	18.68	18.68
2	63.4	.359	22.72	11.36
4	72.1	.396	28.55	7.14
8	83.0	.436	36.19	4.52
16	96.7	.483	46.71	2.92
32	112.6	.541	60.92	1.90
64	132.5	.611	80.96	1.26

In applying the above formula to this particular case for volts, it was decided, in order to make it possible to get the points rather near together on the curve, to assume that it would require ten terms to double the candle-power, and for further convenience it was decided to make 1 candle-power the first term

of the candle-power series. Under these circumstances the formula for the candle-power will be:

Candle-power $= 1.07177^{(n-1)}$, 1.07177 being the number, which raised to the tenth power, will equal 2, or,

Log. candles $= (n - 1)\ .030103$.

In solving for a, b, c and d, it will be necessary to have four equations, and it was decided to use the volts corresponding to 1, 4, 16 and 64 candles:

1 cp. = the first term of the candle-power series,
4 cp. = the 21st term of the candle-power series,
16 cp. = the 41st term of the candle-power series,
64 cp. = the 61st term of the candle-power series,

and the four equations will be as follows:

(1)........	$a + 0b + 0c + 0d = 1.7489629$,	log of 56.1 V.
(2)........	$a + 20b + 190c + 1140d = 1.8579353$,	log of 72.1 V.
(3)........	$a + 40b + 780c + 9880d = 1.9854265$,	log of 96.7 V.
(4)........	$a + 60b + 1770c + 34220d = 2.1222159$,	log of 132.5 V.

in which the second term is the logarithm of the volts.

(5) from (1) and (2)	$20b + 190c + 1140d =$	.1089724
(6) from (2) and (3)	$20b + 590c + 8740d =$	.1274912
(7) from (3) and (4)	$29b + 990c + 24340d =$	.1367894
(8) from (5) and (6)	$400c + 7600d =$	.0185188
(9) from (6) and (7)	$400c + 15600d =$	.0092982 6
(10) from (8) and (9)	$800d =$	—.0092206
(11) from (10)	$d =$	—.0000011526
(12) from (8)	$c + .19d =$	.000046297
(13) from (8) and (11)	$c - .000021899 =$	.000046297
(14) from (13)	$c =$	.000068196
(15) from (5)	$b + -.5c + 57d =$	.00544862
(16) from (5, 10, 14)	$b + .000647862 - .0000656982 =$	.00544862
(17) from (16)	$b =$	.00486646

A similar solution for the ampere-logarithms follows:

(1)	$a + 0b + 0c + 0d = 1.5224442$,	log. of .333 amp.
(2)	$a + 20b + 1190c + 1140d = 1.5976952$,	log. of .396 amp.
(3)	$a + 40b + 780c + 9880d = 1.6839471$,	log. of .483 amp.
(4)	$a + 60b + 1770c + 34220d = 1.7860412$,	log. of .611 amp.
(5) from (1) and (2)	$20b + 190c + 1140d =$	.0752510
(6) from (2) and (3)	$20b + 590c + 8740d =$	.0862519
(7) from (3) and (4)	$20b + 990c + 24340d =$	.1020941
(8) from (5) and (6)	$400c + 7600d =$	.0110009
(9) from (6) and (7)	$400c + 15600d =$	.0158422
(10) from (8) and (9)	$8000d =$	.0048413
(11) from (10)	$d =$	.00000060516
(12) from (8)	$c + 19d =$	.000027502

(13) from (8) and (11)	$c + .000011498 = .000027502$
(14) from (13)	$c = .000016004$
(15) from (5)	$b + 9.5c + 57d = .00376255$
(16) from (5,10,14)	$b + .000152038 + .0000344941 = .00376255$
(17) from (16)	$b = .00357602$

A similar solution for the watt-logarithm follows:

(1)	$a + 0b + 0c + 0d = 1.2713769$, log. 18.68 watts
(2)	$a + 20b + 190c + 1140d = 1.4556061$, log. 28.55 watts
(3)	$a + 40b + 780c + 9880d = 1.6694099$, log. 46.71 watts
(4)	$a + 60b + 1770c + 34220d = 1.9082705$, log. 80.96 watts
(5) from (1) and (1)	$20b + 190c + 1140d = .1842292$
(6) from (2) and (3)	$20b + 590c + 8740d = .2138038$
(7) from (3) and (4)	$20b + 990c + 24340d = .2388606$
(8) from (5) and (6)	$400c + 7600d = .0295746$
(9) from (6) and (7)	$400c + 15600d = 0250568$
(10) from (8) and (9)	$8000d = -.0045178$
(11) from (10)	$d = -.000000564725$
(12) from (10)	$c + 19d = .0000739365$
(13) from (8) and (11)	$c - .000010729775 = .0000739365$
(14) from (13)	$c = .000084666275$
(15) from (5)	$b + 9.5c + 57d = .00921146$
(16) from (5,10,14)	$b + .00080433 + .0000321892 = .00921146$
(17) from (16)	$b = .0084393192$

Substituting the values of a, b, c and d in the general formula for the logarithm of volts, amperes and watts, the final formulas are obtained for this particular case :

$$\text{Log. of volts} = 1.7489629 + .00486646(n-1) + .000034098(n-1)(n-2) - .0000001921(n-1)(n-2)(n-3)$$

$$\text{Log. of amperes} = 1.5224442 + .00357602(n-1) + .000008002(n-1)(n-2) + .000000010086(n-1)(n-2)(n-3)$$

$$\text{Log. of watts} = 1.2713769 + .00843932(n-1) + .00004233318(n-1)(n-2) - .000000094121(n-1)(n-2)(n-3)$$

Applying these formulas to obtain the volts, amperes and watts at 2, 8 and 32 candle-powers to compare with the experimental results :

C. P.	Exp. Volts	Calcu. Volts	Exp. Amperes	Calcu. Amperes	Exp. Watts	Calcu. Watts
1	56.1	56.1	.333	.333	18.68	18.68
2	63.3	63.177	.359	.3622	22.72	22.88
4	72.1	72.1	.396	.396	28.55	28.55
8	83.0	83.165	.436	.4357	36.19	36.23
16	96.7	96.7	.483	.483	46.71	46.71
32	112.6	113.04	.541	.5404	60.92	61.09
64	132.5	132.5	.611	.611	80.96	80.96

If this table is expressed in differences between the experimental and calculated values, there are obtained :

C. P.	Volts	Amperes	Watts
1	0	0	0
2	— .123	+ .0032	+ .16
4	0	0	0
8	+ .165	— .0003	+ .04
16	0	0	0
32	+ .44	— .0006	+ .17
64	0	0	0

The above gave a pretty fair agreement with facts and no further adjustment of the values was attempted. It is evident, however, that such an adjustment might have been made so that the curve, instead of passing exactly through the points, corresponding to 1, 4, 16 and 64 candle-power, would favor all points equally. Then, still retaining the form of the equation, the constants could be recalculated.

Since it is true that the relations between candle-power and watts and between candle-power and life are very nearly the same for all types of incandescent lamps, if this relation for each type of lamp is expressed in percentages of the candle-power and watts at which all types give the same life, it would seem that the relation between candle-power and watts is a much more important one than that between candle-power and volts.

If it be assumed that the relation between candle-power and watts may be expressed by the proportion

$$C : c :: W^x : w^x$$

it can be shown that the value of "x" will not be a constant. Calculate now the values of "x" at 1, 2, 4, 8, 16, 32 and 64 candle-power. The exponent will be true for several decimal places at any one of the candle-powers, if for the calculations, points in the candle-power series be taken only one-tenth of a term apart. Begin with "2 candle-power." Substituting "2" in the formula

$$\text{Candle-power} = 1.07177^{(n-1)}$$

$$2 = 1.07177^{(n-1)}$$

or the logarithm of $2 = (n - 1)$ log. of 1.07177, or,

$$.30103 = (n - 1)\ .030103, \text{ or,}$$

$$n - 1 = 10 \text{ and } n = 11.$$

To find the exponent at two candle-power, divide the difference between the candle-power logarithms for $n = 11$ and $n = 11.1$ by the difference between the watt-logarithms for $n = 11$ and $= 11.1$.

The logarithm of candle-power for $n = 11$ is $.030103 \times 10 = 0.301030$.

The logarithm of candle power for $n = 11.1$ is $.030103 \times 10.1 = .3040403$ and the difference is $.0030103$.

The logarithm of watts for $n = 11$ is $1.2713769 + .00843932 \times 10 + .00004233318 \times 10 \times 9 - .000000094121 \times 10 \times 9 \times 8$, or, $1.2713769 + .0843932 + .00381 - .0000678 = 1.3595123$.

The logarithm for $n = 11.1$ is $1.2713769 + .00843932 \times 10.1 + .00004233318 \times 10.1 \times 9.1 - .000000094121 \times 10.1 \times 9.1 \times 8.1$, or, $1.2713769 + .08523713 + .0038908 - .00007007 = 1.3604348$.

$1.3604348 - 1.3595123 = .00092246$.

$.0030103 \div .00092246 = 3.263$, the exponent sought.

The exponents for the other candle-powers, which were calculated in the same way, are shown in the following table, which affords an opportunity also to correlate the watt-exponent with the specific consumption, so as to make the values independent of the candle-power, volts and amperes of the lamp.

Candle-power	Watts per candle	Watt exponent
1	18.68	3.583
2	11.36	3.263
4	7.14	3.014
8	4.52	2.813
16	2.92	2.644
32	1.90	2.517
64	1.26	2.416

If these values now be plotted in a curve in terms of watts per candle and watt exponent and values be read from the curve at each half watts per candle from 1.5 to 7, the following table is obtained :

Watts per candle	Watt exponent
1.25	2.41
1.50	2.45
2.00	2.53
2.50	2.59
3.00	2.65
3.50	2.71
4.00	2.76
4.50	2.81
5.00	2.86
5.50	2.90
6.00	2.93
6.50	2.97
7.00	3.00

The volt and ampere exponents may be calculated in the same way, but as stated heretofor "it is most convenient to put the data in the form of curves," and so these values are not presented here. I can say, however, that they would confirm the conclusions drawn by Mr. Cady.

THE INTENSITY OF NATURAL ILLUMINATION THROUGHOUT THE DAY.[1]

BY LEONARD J. LEWINSON.

This paper deals primarily with the intensity of illumination produced by natural sources of light, such as the sun, moon and stars, modified by the earth's atmosphere. Experiments were undertaken to secure data under various atmospheric conditions at different periods during the day. To make a complete survey of the subject would involve years of effort. The author recognizes the inexhaustibleness of this field of research, as well as the limitations of the data here presented. The lack of reliable information and the need for data on this subject are felt to justify the presentation of this paper, which under other circumstances would have been withheld until more complete data should become available.

Spectro-photometric analyses of daylight have been made, rendering possible a comparison of artificial and natural illumination, as far as color composition is concerned, and bringing out the fluctuations of color values during the day. A number of papers treating of daylight illumination have appeared, but in all of them there is an almost entire absence of intensity determinations—"foot-candle" values, which are of leading interest to illuminating engineers. To the establishment of the best artificial conditions, a knowledge of natural conditions is essential. Men who deal with lighting problems are in need of data that can be applied in the design of artificial illumination. They should know the order of magnitude of the natural illumination intensity during the day, for which they endeavor to provide a substitute at night, or a reinforcement on dark days. They should appreciate the fluctuations in intensity to which natural illumination is subject—variations of greater extent than are met with in any artificial illumination.

A problem which is open to discussion, and which is of much importance, can be summed up in the question, "Why does the

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

human eye, which is satisfied with an illumination of 2 foot-candles produced at night by an artificial source, require at least 20 foot-candles of daylight for ordinary reading purposes?" It is believed that studies of the kind considered in this paper will shed some light on this interesting question.

Moonlight intensity is of particular interest in connection with street lighting. It has been the chief criterion, particularly in this country, and will probably remain so for years to come. In many towns, lighting plants are operated on a "moonlight schedule," the lamps being operated only when natural illumination is considered insufficient. "What is the illuminating value of

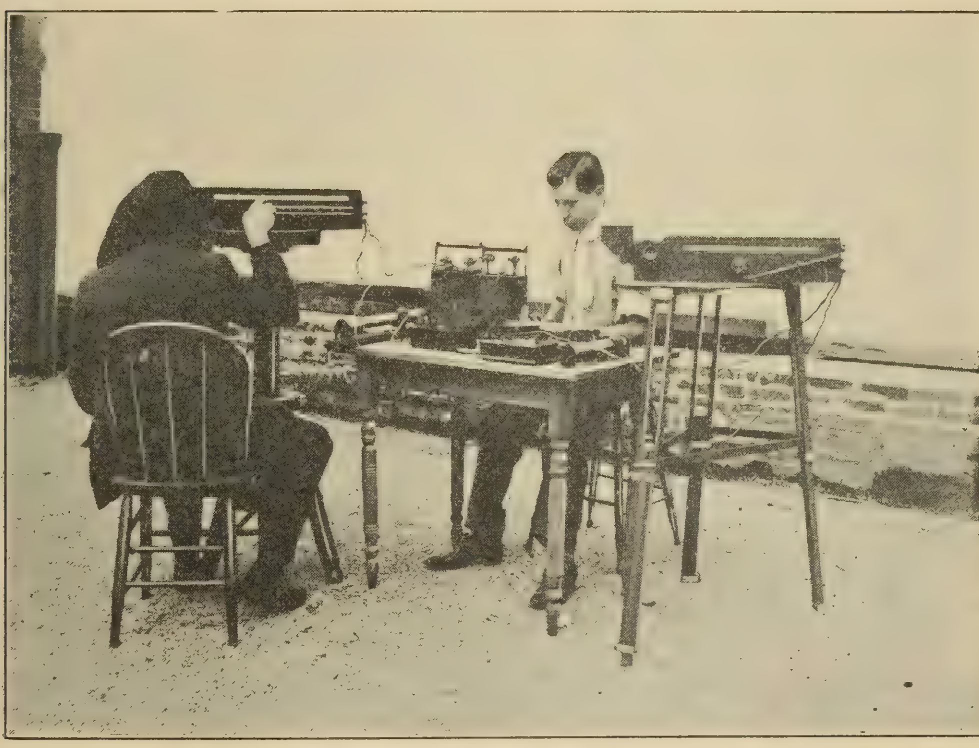


Fig. 1.—General View of Apparatus.

moonlight?" "How does this intensity vary?" These are questions which have long remained unanswered. Now, however, that engineers are approaching the problems of street lighting from a scientific viewpoint, it is essential to know the foot-candle intensity of moonlight and skylight at night.

APPARATUS USED IN TESTS.

Two Sharp-Millar photometers,[1] equipped with miniature tungsten lamps were used. The arrangement of the instruments is shown in Figure 1.

1 For description, see "*Electrical World*" and *Electrical Review*," Jan. 25, 1908.

LOCATION OF TEST STATION.

The experiments were conducted on the roof of the Electrical Testing Laboratories in New York City. There is practically no obstruction to skylight. The roof of the adjoining building toward the west is only a few feet higher than the roof of the Laboratories. On the north side, there are no buildings within one hundred feet, and toward the east and south the space is practically open. When two photometers were used, the test plate of one was horizontal and that of the second was turned so as to be normal to the direct light from the sun or moon. In certain tests, one photometer was used in making both sets of measurements.

ACCURACY OF TESTS.

With unvarying intensity and good color value, a precision of approximately one per cent. can be obtained with the photometers used in these tests. On account of the great color differences and large variations in intensity which were encountered, the precision of the determinations was necessarily somewhat lower. No definite statement can be made as to the accuracy attained. In order to obtain a high degree of accuracy in tests of this kind, it would be necessary to have a number of observers and to use several different methods in determining the illuminating values. For the purposes of this paper, the results attained may be considered as substantially correct.

TEST A.—24 HOURS CONTINUOUS OBSERVATION.

Date : September 9 and 10, 1908.
Sun rises, September 9, 5:33 a. m.
Sun sets, September 9, 6:19 p. m.
Moon full, September 10, 7:45 a. m.

The sky during this test was clear, and practically cloudless throughout the entire 24 hours. There was a slight haze all day, except during the hours immediately preceding and following noon, This haze was slightly heavier in the early afternoon than during the morning. The temperature was about 61°F. during the early morning hours, increasing to 73°F. at noon, and steadily decreasing to 64°F. at 9 p. m., after which it remained about constant until 3 a. m., September 10. Light southwesterly and westerly winds prevailed. The results of the test are recorded in Table I.

TABLE I.

Time A.M.	Illumination in Foot-Candles Horizontal	Normal	Remarks
3.45	0.0008		Temp. 64°F. Rel. hum. 67.5%
4.30	0.0011		Slightly hazy
4.35	0.0018		
4.40	0.0036		
4.42	0.0049		
4.45	0.0063		Temp. 61°F. Rel. hum. 64.5%
4.46	0.0104		
4.48	0.016		
4.50	0.025		
4.52	0.033		
4.55	0.047		
4.57	0.071		
5.00	0.116		
5.04	0.500		
5.07	0.936		
5.15	2.70		
5.20	7.50		Temp. 60°F. Rel. hum. 77%
5.25	16.40		Sun rises 5.33 a. m.
5.37	57.00		
5.40	77.8		Sun just visible
5.44	133.4		
5.50	140	150	
5.56	150	317	
6.06	207	401	
6.15	301	788	
6.20	427	954	
6.30	516	1060	
6.38	645	1370	
6.50	889	1990	
7.00	1190	2630	
7.10	1230	2750	
7.30	1390	3000	
7.42	1560	4070	
7.54	1720	3970	
8.02	2340	4370	
8.15	2540	4660	
8.30	2860	4980	
8.45	2750	5300	
9.00	3500	5190	
9.15	3280	5510	Temp. 73°F. Rel. hum. 64%
9.30	4240	7200	
9.45	4550	6670	Haze increased
10.00	4760	7620	Temp. 72°F. Rel. hum. 48%
10.15	5510	8370	
10.30	5820	8680	
10.45	5350	8560	

TABLE I.—(*Continued*).

Time A.M.	Illumination in foot-candles Horizontal	Normal	Remarks
11.00	3900	5990	Haze heavier
11.15	6420	8780	Haze lighter
11.30	6210	9630	
11.45	6850	9850	Temp. 73°F. Rel. hum. 42%
12.00 M	7070	10060	
P. M.			
12.15	7070	10060	
12.30	8990	11780	
12.45	8990	12420	
1.45	4620	6640	Haze heavier
2.00	5300	6760	Haze decreasing. Rel. Humidity 40%
2.20	4100	6670	
2.45	4100	6370	Slight haze
3.00	3280	5790	
3.15	2660	5290	
3.45	2570	5050	
4.10	1820	4470	
4.45	1130	2850	
5.00	862	2220	
5.30	385	768	
6.15	92.6		Sun sets 6.19 p. m.
6.30	55.7		Moon rising. Rel. hum. 60%
6.45	11.0		
7.45	0.0044	0.0140	
8.10	0.0069	0.0182	
8.35	0.0108	0.0230	
9.00	0.0137	0.0264	Temp. 64.5°F. Rel. hum. 61%
9.20	0.0134	0.0298	
9.40	0.0120	0.0257	
10.0	0.0163	0.0307	
10.22	0.0154	0.0288	
10.45	0.0149	0.0312	Temp. 63.5°F. Rel. hum. 65%
11.00	0.0159	0.0254	
11.35	0.0159	0.0312	
11.55	0.0216	0.0388	Temp. 62°F. Rel. hum. 69%
A. M.			
12.20	0.0183	0.0380	
12.40	0.0139	0.0290	
1.00	0.0154	0.0320	
1.20	0.0144	0.0288	Temp. 61°F. Rel. hum. 73%
1.40	0.0130	0.0245	
2.00	0.0130	0.0269	
2.20	0.0115	0.0302	
2.40	0.0107	0.0250	
3.00	0.0072	0.0240	Temp. 61°F. Rel. hum. 67%

NOTE:—For the sake of brevity, the term "Horizontal Illumination" is used to express the intensity of illumination on the horizontal test plate; the term "normal illumination" expresses the intensity of illumination on the test plate turned toward the sun and moon.

The results are expressed graphically in Figs. 2 and 3. Noon is taken as the starting point; the heavy, continuous line shows the illumination during the afternoon and evening of Sept. 9, the scale of hours being shown at the bottom of the diagram. The thin, continuous line shows the illumination during the mornings of Sept. 9 and 10, the scale of hours at the top of the diagram applying. It will be seen that the p. m. curves read from left to right, and the a. m. curves from right to left. Horizontal illumination intensities are shown in Figs. 2 and 3, because the normal illumination values are available only during the periods when the sun and moon are visible.

Considering first the night illumination, one notes that the sky-

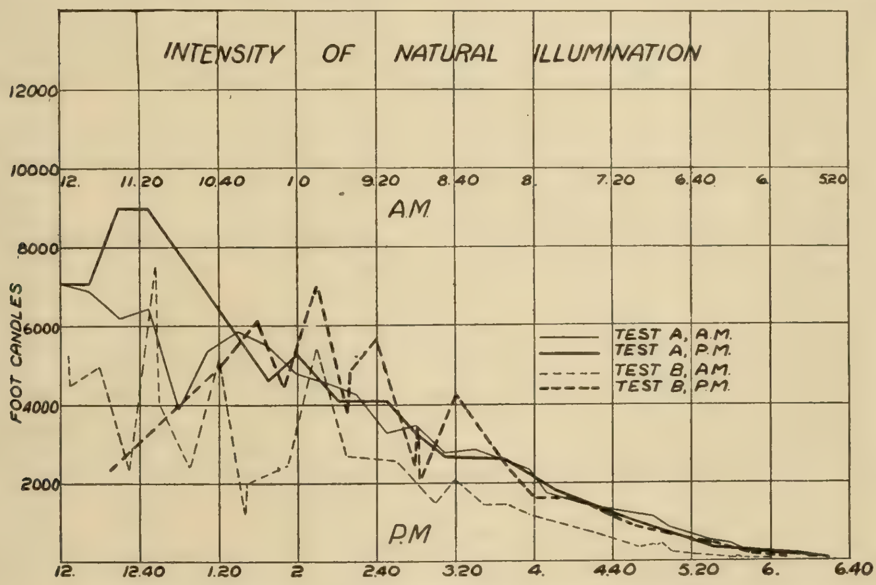


Fig. 2.—Intensity of Natural Illumination in Day Time.

light value approximates 0.001 foot-candle, when the moon is not visible. It must be remembered in connection with this value that the measurements were made in a large city, where artificial sources influence the skylight very perceptibly.

The rate of increase of illumination during the hour preceding sunrise is enormous, the intensity at 5.25 a. m., about seven minutes before sunrise, being approximately 10,000 times that at 4.25. During the hour after sunrise, the rate of increase is relatively small, the intensity at 6.38 a. m. being about 11 times that at 5.37 a. m.

When the sun first appears above the horizon, the horizontal illumination is about equal to the "normal;" after the sun is

well above the horizon, the normal illumination increases more rapidly than the horizontal. During the later morning hours, there is a steady increase of both horizontal and normal illumination, the former again approaching the latter in magnitude as the sun nears the meridian. There is a striking regularity in the rate of change in intensity between 6 a. m. and noon. In the afternoon there is a correspondingly regular rate of decrease until about 6 o'clock, when the falling off becomes more marked, and during the hour immediately after sunset, there is a very rapid diminution.

A fair average figure for horizontal illumination produced by

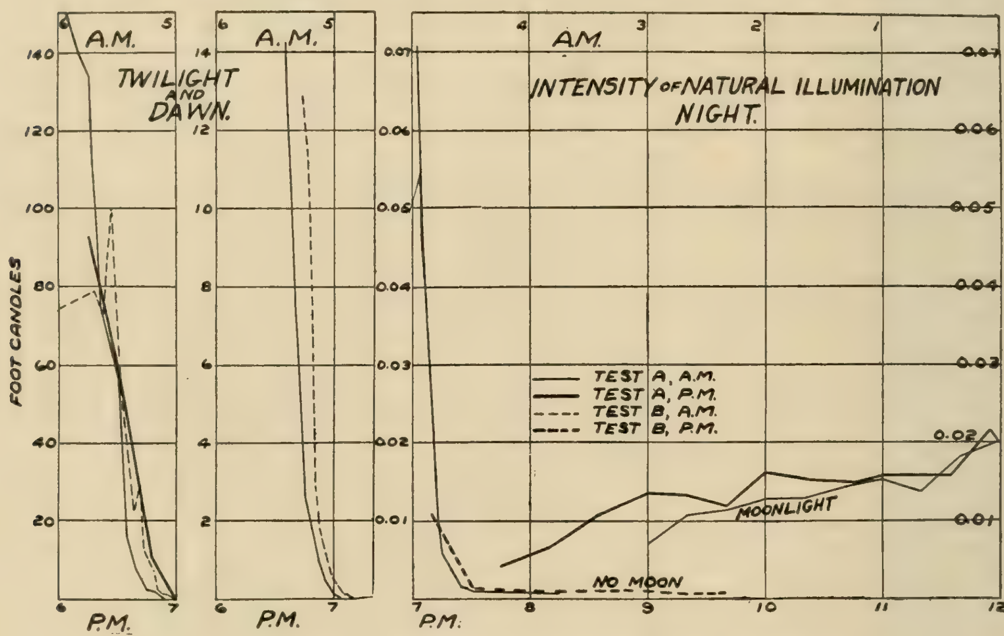


Fig. 3.—Intensity of Natural Illumination at Night—No Moon.

moonlight and skylight on this particular night is about 0.014 foot-candle, between 8.35 p. m. and 2.20 a. m. The "normal" illumination is about double the horizontal. The moonlight illumination is very much more constant during the night than is the sunlight during the day, probably due to the fact that on this occasion the moon did not rise as high in the sky as did the sun.

With noon as a starting point, working forward toward 6 o'clock in the afternoon, and backward toward 6 o'clock in the morning, the illumination curves correspond very closely, except during the hour immediately preceding and immediately following noon, where large fluctuations were noted, due to varying atmospheric conditions.

TEST B.—17 HOURS CONTINUOUS OBSERVATION.

Date: September 1, 1908.
Sun rises, 5.24 a. m.
Sun sets, 6.35 p. m.
No moon.

During the early morning, there was a very heavy mist and the relative humidity was very high, decreasing from 98 per cent. at 4.51 a.m. to 80 per cent. at 10.20 a. m. From 10 o'clock to noon, the per cent. of relative humidity decreased more rapidly to about 48 per cent. The mist gradually disappeared, but the sky became overcast with irregular clouds. In the morning, up to 10 a. m., the wind, which was light, was from the northeast. After 10, it shifted into the south, and later the southwest.

Table II shows the results of the second test.

TABLE II.

Time A.M.	Illumination in Foot-Candles Horizontal	Normal	Remarks
4.51	0.081		Temp. 64°F. Rel. hum. 98%
4.51½	0.076		Very heavy mists
4.52	0.091		
4.53	0.115		
4.55	0.139		
4.56	0.228		
4.57	0.268		
5.00	0.524		
5.01	0.595		
5.03	1.04		
5.07	1.71		
5.09	2.96		
5.11	7.10		
5.12	8.58		
5.13	11.25		
5.16	12.9		
5.18	29.4		
5.21	22.9		Sun rises 5.24 a. m.
5.29	58.4		Temp. 64°F. Rel. hum. 97%
5.33	99.9		
5.37	72.3		
5.42	78.7		
6.00	74.3		
6.10	88.8		
6.11	85.6		
6.12	81.4		
6.15	90.2		
6.17	105.0		

TABLE II.—(*Continued*).

Time A.M.	Illumination in foot-candles Horizontal	Normal	Remarks
6.18	97.5		
6.30	119		
6.33	123		
6.38	167		
6.39	165		
6.51	298		
6.55	438		
6.58	389		
6.59	407		Sun visible through mist
7.06	371		
7.15	514		
7.16	581		
7.30	712	812	
8.00	1170	1470	
8.15	1450	2030	
8.25	1400	2020	
8.40	2070	3070	
8.50	1460	1420	
9.10	2570	4290	Temp. 75°F. Rel. hum. 84%
9.25	2650	3280	
9.35	2700	4470	
9.50	5400	7250	
10.05	2440	2850	
10.20		1750	Temp. 74°F. Rel. hum. 81%
10.25	2000		Sun invisible
10.26	1160		White clouds forming
10.40	5260	5180	
10.55	2400	3140	
11.10	4045	5160	
11.11	7520		Sun unobscured for a moment
11.25	2290	2182	Sun obscured by a cloud
11.40	4925	4940	
11.55	4440	3610	Temp. 84°F. Rel. hum. 59%
11.56	5290	6150	Less hazy
P. M.			
12.10		6150	Cloudy
12.15		7450	
12.25	2330	4770	Mists dispersed—Cloudy
12.40		5300	Clearing. Rel. hum. 54%
1.20	4900	3740	
1.40	6120	5390	
1.55	4380	8570	
2.10	7000	6340	
2.25	3800	7620	Sun unobscured
2.25½	4800		
2.40	5690	7160	

Time P.M.	Illumination in foot-candles Horizontal	Normal	Remarks
3.00	2420	2330	
3.00½	3460		
3.01	2080		
3.20	4260	5600	
3.40	2820	5200	
4.00	1680	2660	
4.20	1610	1080	Heavy cloud obscuring sun
4.50	935	504	
5.10	670		
5.30	510		
5.50	218		
6.10	94.2		Clear directly overhead
7.10	0.0107		Cloudy
7.30	0.0016		
8.00	0.0012		
8.30	0.0013		
8.55	0.0013		Clouds breaking
9.25	0.00085		
9.40	0.00103		

The broken line curves on Figs. 2 and 3 constitute a graphical representation of the above results. Here again, the rapid changes during the hour immediately preceding sunrise and the hour following sunset are noted. The fluctuations in intensity during the day are very marked, the ever-shifting mists during the morning and the heavy clouds which obscured the sun at times during the afternoon causing these variations. The average intensity during the afternoon, particularly after one o'clock, is higher than that in the morning, due to the disappearance of the heavy mists. Some of the intensities observed are considerably higher than the values at corresponding periods during the first test, probably due to the fact that the cloud formation at certain times caused an increase in the horizontal illumination intensity. This phenomenon has already been pointed out by Dr. Edward L. Nichols, in his paper on "Daylight and Artificial Light,"[1] in which he shows a fourfold increase of illumination during eight minutes preceding the obscuring of direct sunlight by the formation of a storm cloud.

Referring to Fig. 3, it will be seen that the skylight approximates 0.001 foot-candle after 7.30 p. m. There are slight variations from this value incident to the breaking up of the clouds after 9 o'clock.

[1] *Transactions* of the Illuminating Engineering Society, Vol. 3, No. 5 (May, 1908).

It is of interest to note that at a few minutes before dawn and a few minutes after sunset, the illumination is about 2 foot-candles; such an intensity produced by an artificial source, as stated before, is considered sufficient for reading purposes. In making the tests, however, it was found that when the natural illumination was 2 foot-candles, it was impossible to read the instruments without the aid of artificial light. On the clear day (Test A.) the illumination was found to be 2 foot-candles at about 25 minutes before sunrise and 25 minutes after sunset. In Test B, when the sky was clouded or obscured by a heavy mist, this value was obtained at about 15 minutes before sunrise and 15 minutes after sunset.

TEST C.—10 HOURS CONTINUOUS OBSERVATION.

Sun sets, 7.03 p. m., August 12
Sun rises 5.04 a. m., August 13
Full moon 12.15 a. m., August 12

During this test, the per cent. of relative humidity was very high, averaging about 90 during the night. Up to 9 o'clock, there were light clouds in the sky. Between 9 and 10 p. m., the sky was cloudless. Subsequently a haze formed causing the appearance of rings around the moon. Light south to southeast winds prevailed.

The results of the tests are shown in Table III.

TABLE III.

Time P.M.	Illumiuation in foot-candles Horizontal	Normal	Remarks
6.55	19.7		Light clouds. Rel. hum. 87%
7.07	3.08		Sun set, 7.03 p. m.
7.22	0.406		Temp. 76°F. Rel. hum. 88%
7.24	0.354		
7.25	0.330		
7.40	0.016		Temp. 75°. Rel. hum. 81%
8.06	0.0011		
8.30	0.0016	0.0061	Moon under light cloud
9.00	0.0040	0.0297	Sky cloudless
9.32	0.0066	0.0210	
9.65	0.0079	0.0252	
10.26	0.0080	0.0291	Ring around moon
10.48	0.0105	0.0244	Slight haze
11.30	0.0125	0.0305	
A. M.			
12.03	0.0119	0.0282	
12.32	0.0140	0.0324	
1.23	0.0123	0.0312	

TABLE III.—(*Continued*).

Time A.M.	Illumination in foot-candles Horizontal	Normal	Remarks
1.30	0.0127	0.0220	
2.00	0.0127		Temp. 74° F.
2.20	0.0142	0.0207	Clearer. Rel. hum. 89%
3.05	0.0102	0.0263	Double ring around moon
3.30	0.0096	0.0174	
4.05	0.0091	0.0154	
4.15	0.0143		
4.20	0.0193		
4.26	0.0608		
4.36	0.3044		
4.45	2.212		Sunrise, 5.04 a. m.
5.30	193.0		

On Fig. 4 are shown the moonlight curves derived from the results of Tests A and C. The continuous line represents the in-

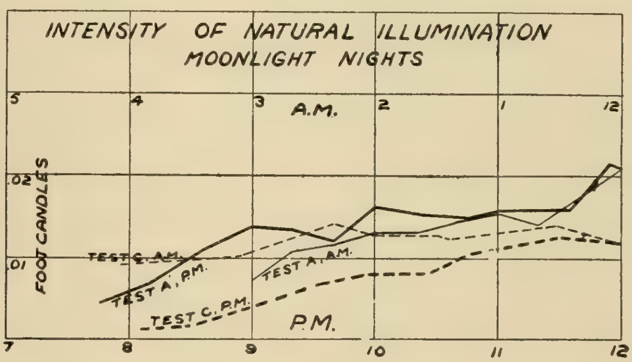


Fig. 4.—Intensity of Natural Illumination on Moonlight Night.

tensity of the full moon during a clear September night. The broken line represents the intensity of the full moon during a night in August, the sky being almost cloudless, but somewhat hazy. During the August test, the intensity averages are somewhat lower than the September test, due probably to the haziness encountered during the earlier test.

Conclusions regarding natural illumination under conditions described are as follows :

Certain cloud formations have the effect of increasing the intensity of illumination by diffusion. Other clouds act as absorbing media, and decrease the illumination intensity. Variations in intensity due to clouds, are often of a large order, and sometimes occur suddenly.

In the absence of clouds, the rate of change of intensity, between the hours of 8 a. m. and 4 p. m. is regular.

The rate of change of intensity during the hours of dawn and twilight, is very high.

The skylight value at night, when there is no moon, is approximately .001 foot-candle.

The intensity of moonlight is about .014 foot-candle.

Daylight illumination varies in intensity from 2000 to 8000 foot-candles, between the hours of 8 a. m. and 4 p. m.

It is hoped that the data herein presented may serve as an acceptable first step toward the establishment, on a quantitative basis, of the facts in regard to natural illumination. The author wishes to acknowledge his indebtedness to various persons, in particular Messrs. H. E. Allen and S. Ulmar, for valuable assistance in making the tests outlined in this paper.

DISCUSSION.

Mr. Carl Hering:—This paper is of special importance, because reliable information concerning the luminous value of daylight seems to be very meager, and what there is, is often stated indefinitely in books, and is sometimes unquestionably wrong.

In my opinion, one of the reasons why a knowledge of the value of daylight is important is that our eyes can be assumed to be best adapted to natural daylight illumination, and therefore if artificial or night illumination corresponds with daylight, the best use can be made of our eyes.

It may be of interest to call attention to the fact that the maximum illumination obtained by the authors, about 12,000 foot-candles, if none of it is absorbed, would correspond to the intrinsic brightness of the Welsbach mantle, according to the figures in Dr. Bell's book, after being reduced from candles per square inch to foot-candles. I do not assume any responsibility for the original data, but simply for the conversion factor of 452, by which candles per square inch are multiplied to reduce them to foot-candles. It is perhaps hard to conceive that a piece of white paper exposed to daylight is nearly as bright as a Welsbach mantle, but if the figures are correct, such is the case.

Mr. J. E. Woodwell:—This paper presents a great deal of

data valuable to the illuminating engineer, but it is a question in my mind as to whether the two values enumerated, namely, the horizontal component of the daylight illumination, or the normal component is as important in practice as the vertical component. Practically all of the light which enters our modern structures comes in through vertical windows. It is also of interest to determine the illumination of the exterior walls of buildings, and the consequent effect of reflection upon the streets and adjacent buildings. In future work of this kind, which I hope will be continued, I trust that measurements will be made of the vertical component of illumination, so that there may be obtained some practical data upon which to determine the intensity of daylight entering vertical windows.

Mr. Emile G. Perrot:—The question of daylight illumination in buildings is one that has occupied my attention for some time. On account of having to place buildings in positions where they would be best lighted in daytime, I have looked up the subject of the relative values of daylight at various times of the year, at the equinox, and also in the winter and in the summer. The test recorded in the paper was made in September, and thus does not give any real information from a practical standpoint to be used in designing a building.

In hospitals it is very essential to have the maximum amount of sunlight penetrate the building through the windows for the longest time possible. There was a paper written and published in a magazine called "*The American Architect and Building News*," March 3, 1906, entitled "The Orientation of Buildings," in which an architect reported a number of investigations on the subject, and plotted the effect of the sunlight, not only for the equinox but also for the winter months and the summer months; the article covers the subject very thoroughly. It must be remembered that the sun in winter is lower in the horizon than it is in summer, and consequently the penetration of sunlight through a window in a vertical plane would be much further into a room in the winter than in summer. Moreover the sun sets and rises in different positions at different times of the year, so that the position of a building which is correct for one time of the year may be wrong for another.

Mr. V. R. Lansingh:—For the sake of record, I should like

to call attention to an article in the "*Technology Quarterly*" for September, 1905, as published by the Massachusetts Institute of Technology. This article, by Mr. William Atkinson, is entitled "The Orientation of Buildings and of Streets in Relation to Sunlight."

Mr. R. S. Hale:—(By letter). The subject of the variation of the natural illumination throughout the day arises frequently when the schedules upon which street lamps should be run. In different cities the time varies from approximately 4400 hours, down to as low in some cases as 3700 hours.

A schedule of 4000 hours provides for turning on one-half hour after sundown and turning off approximately one-half hour before sunup. It is obvious, however, that the time in relation to sundown and sunup should vary both with the time of year and with the latitude. In Northern latitudes the summer twilight is very much longer than the twilight at other seasons of the year.

Irrespective of the absolute quantity of light, there is also a question as to how much light is needed and there is no doubt that in the morning hours when the streets are nearly vacant, the lamps may be turned off earlier in relation to the sun than would be wise in turning them on at night when the streets are full of traffic. There is also here a relation due to the retina of the eye. When people have been out all night so that the retina of the eye is enlarged, less light is needed in the early morning hours than would be needed at night after daylight.

In Boston a good many years ago a schedule was selected by actual experiment, the city officials and the officials of the old Boston Electric Light Company going out in the streets and determining on several successive nights at just what time the lamps were needed and again, at just what time in the morning the lamps could be satisfactorily turned off. As a result a schedule was obtained which turns on the lamps only a few minutes after sundown and turns them off considerably more than one-half hour before sunrise, the total of the schedule amounting to 3828 hours, and this schedule has given good satisfaction for many years, not only in Boston itself where it is part of the contract, but in adjoining towns where the town officials have

the privilege of changing the schedule at any time that they see fit.

A thorough study of this subject will enable towns to make an appreciable saving in the hours of street lighting, without any deterioration of the service, or for the same hours that the lamps are in use to afford a considerably improved service by giving the light at times when it is needed.

President Bell:—The Chair would call attention to the fact that the value given in the paper was the light actually received from the sun, directly, whether the sun was clear or the light came through a cloud. Daylight is often spoken of in a very loose way, meaning thereby any light that happens to filter through to the place designated, but I think it is well for all of us to remember that these particular investigations,—which should have been made long ago, and we are very glad to have them before us now—do not deal with that loose meaning of the word daylight, but with a precise thing, to wit, the direct rays of the sun. In other words, it shows what is obtained from the sun at various altitudes under various conditions.

Mr. Leonard J. Lewinson:—In answer to Mr. Woodwell's remark referring to the measurement of vertical illumination, I wish to repeat that this paper serves only as an introduction to the subject. In attempting measurement of vertical illumination, to my mind, there would be considerable question as to the direction in which the vertical test-plate should be turned: directly towards the sun, away from the sun, etc.

I should like to point out that the illumination measurements during the day as given in this paper represent sunlight plus skylight.

Referring to the statement concerning the difficulty in reading instruments with 2-foot-candles natural illumination, it should be remembered that natural illumination is widely diffused. If a small enclosure were equipped with a natural light source, say, through a hole in the ceiling so arranged as to give a general illumination of 2-foot candles on a certain test plane, one could probably read any instrument on this plane without any difficulty.

Mr. Bassett Jones, Jr.:—(Communicated after adjournment). Much has been heard lately of the intensity and quality of day-

light illumination, and the use of a proposed quantitative and qualitative mean value of daylight, as a standard in artificial illumination. The writer believes that no such standard can be established, or used if established, for the simple reason that it is impossible to reproduce artificially the quality of daylight, properly so called, and without its peculiar quality, its quantity would be unbearable.

The daylight actually used by the human eye for purposes of ordinary vision, is rarely the light of the sky, but the light of the sky reflected from the usually soft and colored surfaces of nature. Only occasionally are our eyes raised sufficiently above the horizon to bring the center of vision within the region of "skylight," and if long retained in this position the result is certainly anything but pleasant even with a sky considerably overcast.

Measurements of wave length and intensity of daylight taken from any part of the sky cannot therefore be taken as a criterion for artificial illumination. The need is for measurements of the wave-length and intensity of the light actually reflected into the eye from the environment—not measurements taken in any particular direction, but a mean value of the light coming in every direction below the normal angle of the eye-brows. All direct light above this angle should be effectually shut off.

In seeking to apply such a standard, it must be remembered, however, that in our life out-of-doors nature presents to us an almost infinite variety of colors and tones. There is no such thing in natural light as a normal or average, and even the actual arrangement of colors and tones that the eye receives at any instant is very different from the colors and tones of the instant before. In nature all is in constant kaleidoscopic change. The eye is never given an opportunity to weary or grow fatigued with any single combination, and over all is thrown a wonderful interlacing of shadows and darker spots and regions that greatly tone down the whole landscape and add much to its restfulness. Nature, you will observe, is very chary of the use of high lights. Her white is always mixed with gray.

Then too, there is no confinement. It is well enough to talk of 2000 horizontal foot-candles when the area in question is a circle perhaps ten miles across; when the light source is ap-

proximately 90,000,000 miles away, and when there are no walls and no ceiling. Imagine any such intensities in the largest room you please, with the light source, relatively speaking, just above your head.

It is impossible to reproduce indoors an environment in any way approaching nature, and without the environment both the quality and quantity of the light must be correspondingly altered.

The criterion for artificial illumination cannot be settled by light, but by the eye. That light which experience and physiology shows us to be the best under each set of conditions is the proper light under those conditions, and not some other quality and quantity of light suitable for some totally different set of conditions. That the eye has evolved under the stimulus of reflected daylight in one environment, can furnish no test to the adaptability of the organ to the stimulus that would be applied to if by daylight reflected from a totally different environment.

There is one more point I desire to present, in connection, however, with Prof. Nichols' paper referred to by the author of the paper under discussion.

Prof. Nichols draws attention to the fact that "the maximum of illumination for the normal eye is in the same region of the spectrum as the maximum of the energy curve of sunlight." This coincidence he rightly attributes to evolution, but the coincidence is not principally due, I think, to energy relations, as his paper leads one to suppose. It is largely a matter of *color* relations. If it were a matter of energy, only we should expect that all eyes developed under the stimulus of sunlight would have the maximum of illumination in the same region of the spectrum. This is not true. (See *"The Colour Sense,"* Grant Allen; *"A Study of the Image-forming Power of Various Types of Eyes,"* Cole, N. J.; *Proc. Am. Acad. Arts and Sciences,* 1907; Minkiewicz, R., *Arch. de Zool. Expér. et Gén.*, 1907; H. S. Jennings, *"The Behavior of the Lower Animals."* Much has been written on this subject that is of vital interest in this connection. The fact is that the eye is most sensitive in that region of the spectrum which enables the organism to react to its environment with the most useful results, as to food-getting and bodily protection. Higher aesthetic features of color reaction make their appearance in man and greatly complicate the problem. Interesting con-

clusions should, however, be drawn from the very general use of green and yellow as basic pigments in nature.

Professor Cattell, in Ward and Oliver's *"System of the Diseases of the Eye"* draws attention to the fact that on purely biological grounds the color for which the human eye should be best adapted as to visual powers is yellow, since the environment under the influence of which the eye has been primarily developed in previous geological ages was of a general yellowish tone, and ability to distinguish varieties of shade or intensity in this tone would have been most useful. In later periods, the environment become generally greenish yellow and even green in tone, and under these conditions powers of vision in green light would be superimposed on those in yellow light. The modern eye having behind it the influence of the phylogenetic accumulations of countless generations living under such conditions should indicate in the reactions produced during its post natal, or ontogenetic, development a characteristic lack of interest in those tones or shades for which it is primarily adapted, and a characteristic intensity of reaction and interest in more or less novel colors.

The above relation is found to exist. The first colors to which the infant reacts with interest are blues and reds—not yellows, greens or whites. The perception of these last three colors being productive of little or no interest. Binet (*Revue Philosophique* for 1890) shows that yellow is productive of the least interest. He places white between green and yellow, but Baldwin, Shinn and recent investigators have placed green between white and yellow. The writer has himself conducted a series of experiments on the infant's eye with a view to determining what relation, if any, exists between environment and the reaction to intensity and color of light, the results of which he hopes to present to this Society in due time. His results so far quite bear out the latter order, but he is even disposed to consider white in a confined environment even still less normal—in fact under many conditions, white is productive of a subjective excitement quite deleterious.

The above shows, I think, the necessity of considering the many factors not purely physical, brought into play before any empirical standard of intensity and color of artificial light is accepted.

Two interesting approximate results of these experiments may however, be given here. 1. The proper intensity of perfectly diffused light appears to vary somehow with the volume of the enclosed lighted space. The factor of variation is different with different colors of light and environment. 2. Artificial light of a predominating yellow or greenish tone is far less excitable in the case of the normal eye and consequently will be in the long run less injurious even than white light which produces an unnatural nervous reflex (note the restful effect of the cool natural greens and yellows used in decoration). Practical application of these results may be made with regard to certain forms of vapor lamps, and in proper tinting of reflectors for general use with tungsten lamps and similar illuminants approaching the characteristics of pure white light. The results may also be of service in selecting the color of illuminants whose light is to be reflected for decorative environments of any given tone and color.

THE INTEGRATING SPHERE IN INDUSTRIAL PHOTOMETRY.[1]

BY CLAYTON H. SHARP AND PRESTON S. MILLAR.

The need for suitable appliances to facilitate the determination of the mean spherical candle-power or of the total luminous flux from sources of light is one which has made itself felt in practical photometry quite recently. Those, however, who have gone into the subject of photometry more from the theoretical side have long realized the importance of these quantities, and have endeavored to anticipate the need for appliances with which they might be determined.

As far back as the exhibition of the Franklin Institute in Philadelphia in 1884, measurements were made of the mean spherical candle-power of incandescent lamps, and through these measurements this term was introduced into lamp practice in this country, though its real significance remained obscured for many years.

The method used by these early experimenters was to determine the actual candle-power of the lamp in a large number of different directions uniformly distributed over an imaginary sphere surrounding the lamp. This method, which has been employed many times since that day, is very laborious, but leads to substantially correct results.

Blondel in 1892, was the first, we believe, to propose the use of an integrating, or summation, apparatus whereby a measure could be obtained of the mean spherical candle-power or of the total flux at one setting, and he reduced his ideas to the form of a concrete apparatus which he called a lumenmeter.

Dr. Kennelly has more recently produced a lumenmeter founded on quite a different principle in which mechanical integration is employed.

The most successful summation devices hitherto have been the integrating photometers of the late Prof. C. P. Matthews. These ingenious devices have been used with great success and

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

have contributed considerably to the progress of the art in this country.

The simplest form of integrator is one which was first put into practical form by Ulbricht in 1900 and which often goes under the name of the Ulbricht Sphere.

Ulbricht's integrator consists, briefly of a hollow sphere containing the source of light, and coated inside with a white diffusing paint. Into the side of the sphere is set a small window of diffusing glass, the brightness of which, when the direct rays of the light are screened from it, measures the total luminous flux within the sphere.

The integrating sphere has been used abroad in a few laboratories, chiefly in the study of arc lamps. Spheres have been built also for the study of incandescent electric lamps. Descriptions and discussions of the sphere have appeared in the foreign technical press during the past eight years. Possibly because the Matthews integrating photometer has been used in the leading photometric laboratories in this country, we have been slow to investigate the merits of the integrating sphere, although its simplicity and other meritorious features have been appreciated.

The use of the hollow sphere as a photometrical integrating device is founded on the following theoretical considerations:

THEORY OF INTEGRATING SPHERE.

If a source of light having a uniform distribution of candle-power is suspended at the center of a hollow sphere, the illumination at any point of the surface of the sphere is proportional to the mean spherical candle-power or to the total luminous flux of the source. If, however, the source be moved away from the center, this relation no longer is true. Now, let the interior of the sphere be coated with a white, diffusely reflecting, coating, obeying Lambert's law. With such a coating in place, the illumination at any point of the surface may be regarded as being made up of two component parts; first, that due to the light falling on it directly from the source, and second, that due to reflection from all other portions of the surface of the sphere.

If the source of light is not centered in the sphere, or if its candle-power distribution is irregular, the illumination due to

the first component will be non-uniform, but the component of illumination due to reflection from other parts of the sphere will be uniform in all cases and will be proportional to the total flux of light of the source and independent of the distribution of the same. Therefore, by isolating and measuring this component of illumination, a measure of the total flux is obtained.

That the illumination on any portion of the interior of the sphere due to the light reflected from any other portion is independent of the position of the latter and depends on its area and its surface brightness only, may be proved as follows:

In a sphere of radius r the illumination at a point C produced by light emitted by another portion of the surface of

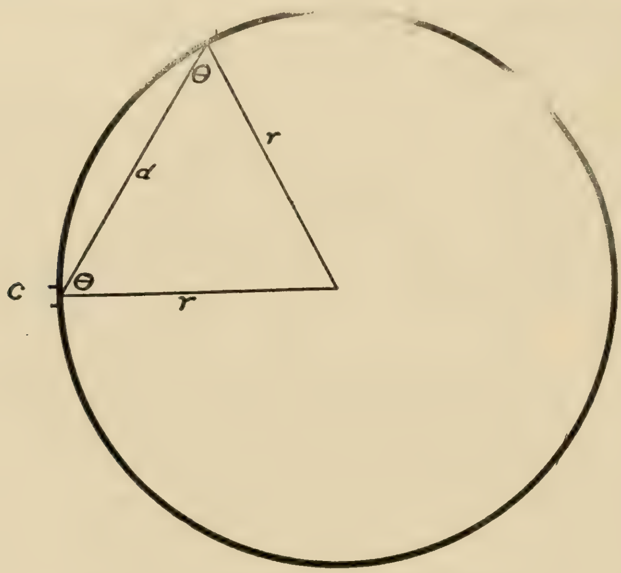


Fig. 1.—Diagram of Relation of Integration.

area Δ A at a distance d from the first, under the assumption that the surface obeys Lambert's law both for emission and for incidence, will be,

$$\Delta E = \frac{e \Delta A \cos^2\theta}{d^2}$$

in which e is the intrinsic brightness of the area Δ A considered as a source of light. Substituting for d its value $2r \cos\theta$, there is obtained,

$$\Delta E = \frac{e \Delta A}{4r^2}.$$

The absence of any variable distance or angle in the above

equation shows that this illumination is independent of the location of the area ΔA. Hence each element of the surface of the sphere will contribute to the point C an intensity of illumination which is directly proportional to the illumination which it itself receives or to the flux of light which it receives. The total illumination at the point C will therefore be proportional to the total flux of light falling on the interior of the sphere; that is, to the total luminous flux of the lamp which the sphere encloses.

In the practical application of the above principle a hollow sphere, which is coated within with a very dull surfaced white paint and is so arranged that a lamp or lamps may be placed inside it, has a small opening or window, conveniently located, which is filled with a piece of depolished white glass, one surface of the glass being made the continuation of the inner surface of the sphere. To meet the condition that the window shall be illuminated only by light reflected from the rest of the sphere, a small white screen is interposed between the lamp and the window.

The presence of this screen, the indirect consequences of which are not taken account of in the simple theory of the sphere as given above, introduces the only serious source of difficulty of error in connection with this method of integration. As a disturbing factor the screen acts in two ways, first by preventing the light from certain portions of the sphere from illuminating the window, which is partially compensated for by the light reflected from the side of the screen which is turned towards the window and, second, by preventing some of the flux of the lamp from reaching the surface of the sphere directly. The latter effect is partially compensated for by the light reflected from the side of the screen which is towards the lamp. The magnitude of each effect varies with the size of the screen. With very small sources of light such as an open arc the screen can be very small and these effects will be negligible even with spheres of small diameter. With sources of large size such as arc lamps with opal globes, the screen must have a very considerable size and the error which it may produce has a corresponding magnitude unless the size of the sphere is also correspondingly increased. Accordingly spheres have been built as large as three

metres in diameter. With smaller spheres where screen-errors cannot be sufficiently reduced by proper construction and location, recourse may be had to the use of a partially translucent screen. The degree of translucency must be found by experiment such that the light which the screen transmits to the window exactly compensates for the loss caused in other ways by the presence of the screen.

During the past two years experiments have been made with

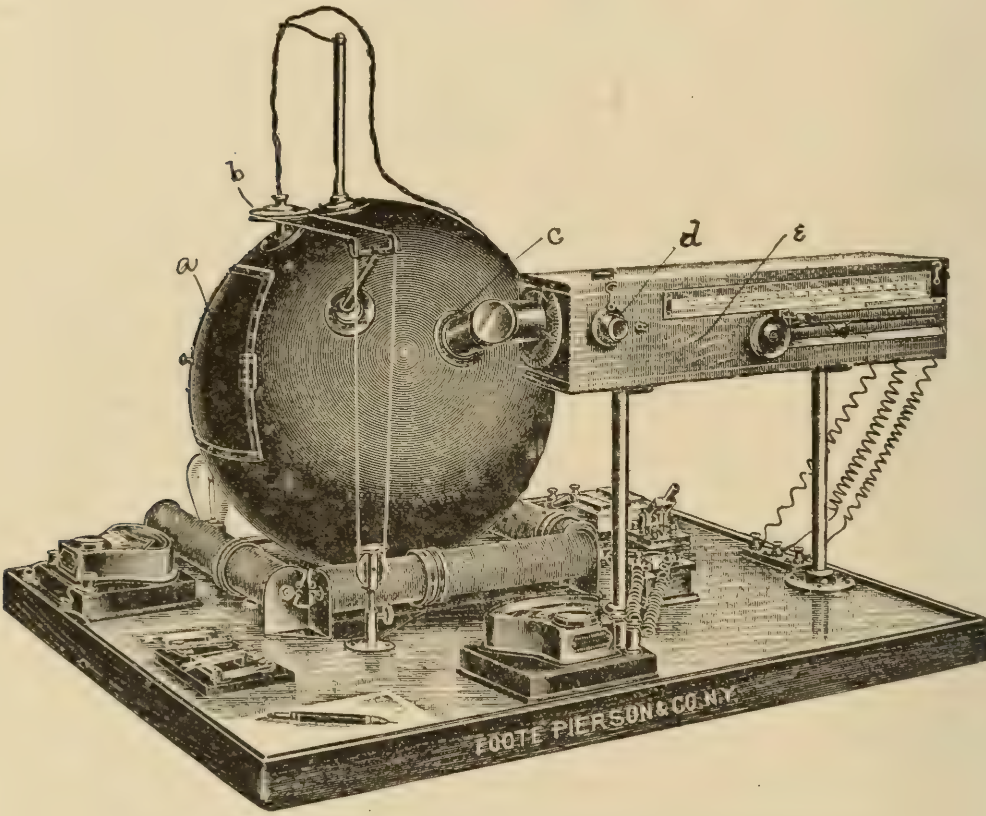


Fig. 2.—Eighteen-inch Integrating Sphere Equipped with Photometer.

integrating spheres at the Electrical Testing Laboratories in New York with uniformly favorable results. Four different sizes of spheres have been used. Three, respectively 11 inches, 18 inches and 30 inches in diameter, have been used with incandescent lamps (Figs. 2 and 3). One approximately 80 inches in diameter (Figs. 4 and 5) has been provided for tests of arc lamps and large incandescent lamps, gas lamps, etc.

DESCRIPTION OF SPHERE.

As means of meeting photometric requirements are of particular interest to the membership of this Society, the construction of spheres will be described from the photometric rather than from the mechanical standpoint. The 18-inch sphere illustrated in Fig. 2 is typical of the smaller spheres. It is provided with a hinged door, A, through which the test-lamp is inserted. B is a shaft on the lower end of which a screw-thread socket is

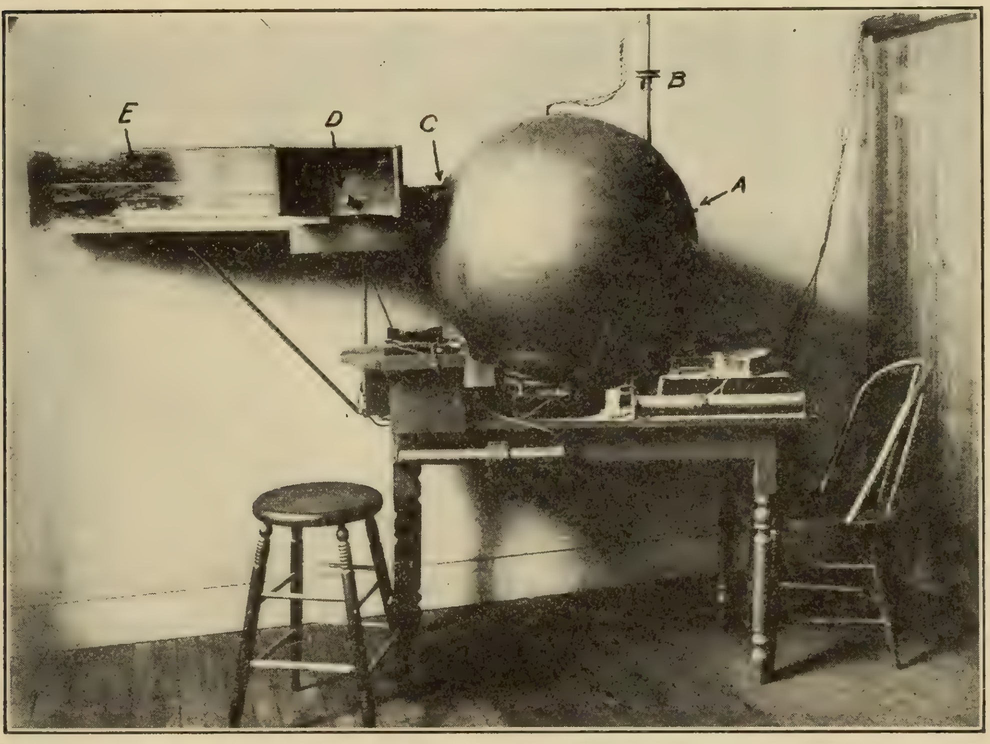


Fig. 3.—Thirty-inch Integrating Sphere Equipped with Photometer.

fixed. As shown in the cut, this shaft and socket may be turned by pulling a cord which passes over the shaft pulley. To mount an incandescent lamp in the sphere, it is necessary merely to thrust the lamp base into the socket and rotate the latter by means of the cord until the lamp is screwed home. A reversal of this procedure unscrews the lamp. C is a small window fitted with translucent glass having the property of substantially uniform transmission of light of all wave-lengths throughout the visible spectrum. The brightness of this translucent glass as viewed

through the photometer from D, is proportional to the total light flux of the source in the sphere.

Between the light-source and the translucent glass window is placed a screen of the same kind of translucent glass with which the window is equipped. This screen is reduced to the smallest possible dimensions, the only requirement being that all parts of the light-source shall be obscured from the translucent glass window.

The interior of the sphere is provided with a white diffusing

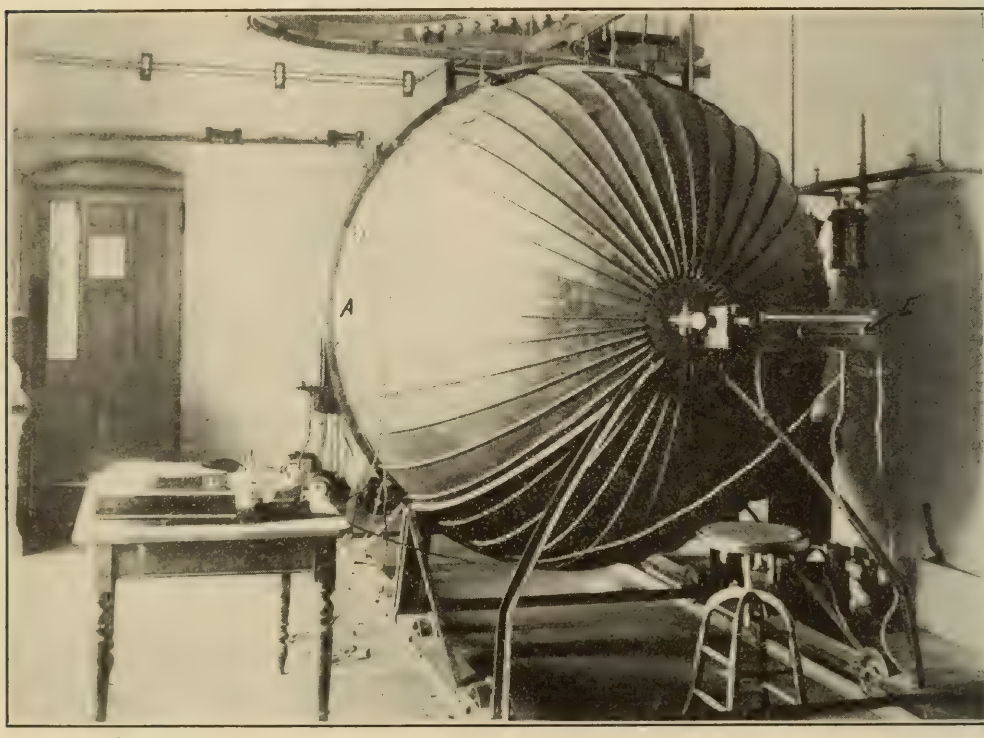


Fig. 4.—Eighty-inch Integrating Sphere Equipped with Photometer.

coating in the selection of which the following necessary features have been considered:—

Nearest approach to perfect diffusion.
Absence of selective absorption.
Permanency of surface.

All exposed interior parts of the sphere, such as lamp mountings, etc., are covered with the same coating.

The large sphere illustrated in Figs. 4 and 5 is composed of hemispheres separated along a vertical plane, and mounted upon flanged wheels running on rails so that the hemispheres may be

separated readily. The door A is provided in order to give access to a standard lamp socket F (Fig. 5). The translucent glass window C is shown in Fig. 5, while the photometer attached to it is shown in Fig. 4. The light from the standard lamp F is obstructed in the direction of the window C by a translucent screen shown in Fig. 5. The light-source to be tested may be located in any part of the sphere. The apparatus in this case is

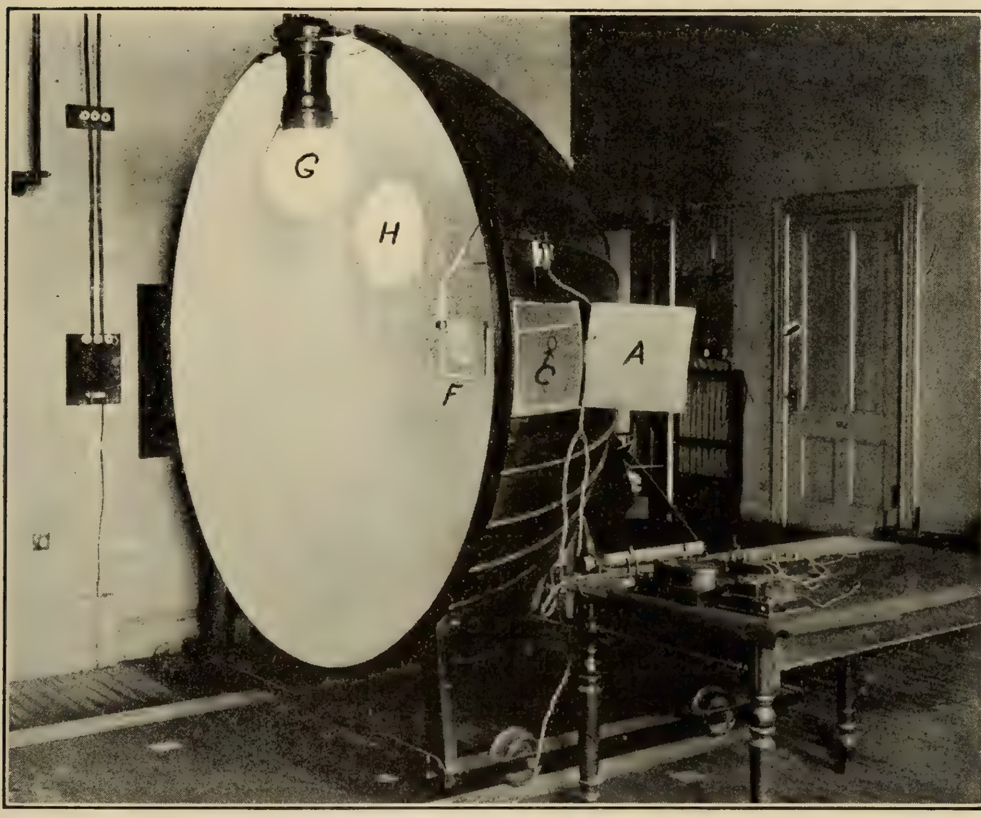


Fig. 5.—Interior of Eighty-inch Integrating Sphere.

designed particularly for use with arc lamps, which are inserted through an aperture in the top of the sphere, or by separating the hemispheres. Other illuminants may, if desired, be inserted through an aperture in the bottom of the sphere, (not shown in illustration) In all cases, however, the translucent screen H must be so located as to screen the light-source under test from the window, C. In other respects, the large sphere is constructed along lines similar to those of the small spheres.

SOME DIFFICULTIES ENCOUNTERED IN THE USE OF THE SPHERE.

A light source having a large surface absorbs a certain percentage of the total light flux in a sphere. Thus the frosting on a lamp bulb in a small sphere, and an opal arc lamp globe in a large sphere, may absorb enough light to reduce the illumination upon the translucent glass window materially. To obviate this difficulty, the larger spheres are standardized by an incandescent electric lamp standard, after the lamp to be tested has been placed in the position which it will occupy during the test. By this means the absorption by the test lamp is compensated for.

In the smaller sphere, the best means of overcoming the difficulty of light absorption is to use standard lamps of the same character as those to be tested, relying upon the substitution method implicity.

Examples of the errors encountered in this connection are as follows:—

Absorption of light by 12-in. opal globe in 80-in sphere	3%
Absorption of light by enclosed arc lamp in 80-in. sphere	5%
Absorption of light by discolored bulb, 16-c.p. lamp in 11-in. sphere...	1%

As has been pointed out above, the screen between the lamp and the translucent window is the chief source of error in the sphere; hence, it is to this feature of construction and arrangement that the experimental study of the authors has been chiefly directed. As a convenient means of testing the screening arrangement, use has been made of an incandescent lamp with very dissymmetrical light distribution produced by painting one side of the bulb black.

Tests of small spheres with a lamp of distorted light distribution, as described above, have shown that when an opaque screen is used and the unobstructed light from the lamp falls upon that portion of the interior surface of the sphere which is opposite the window, the latter is brighter than when the same area of the sphere is covered by the shadow due to the opacity of the side of the lamp bulb which is painted black. This result indicates that the illumination of the window is influenced too little by the light which falls upon the opaque screen. Examples showing the extent of this effect appear in the following:—

DECREASE IN WINDOW ILLUMINATION WHEN SHADOW FROM LAMP BULB FALLS UPON SIDE OF SPHERE OPPOSITE WINDOW.

Diameter of sphere. Inches	Per cent. decreased window illumination
18	11
30	6
80	negligible

The screen must be of sufficient size to screen effectually all parts of the light-source from the window. Since it is desirable to use always one and the same screen, it is necessary to employ a screen approaching in size the largest light-source to be tested, the particular size varying with the location of the screen in the sphere. Under these circumstances, it has been found that when an opaque screen is used, the accuracy of results is dependent upon the size of the light-source tested. So, for example, in the 80-in. sphere the following differences have been found between results obtained with an opaque screen of the size which it is desirable to use, and those obtained with the smallest opaque screen which could be used in connection with the particular light-source investigated.

Lamp	Per cent. difference between determinations with large and small opaque screens
100-c.p. carbon filament	2
32-c.p. carbon filament	3
16-c.p. carbon filament	4
8-c.p. carbon filament	5
4-c.p. carbon filament (sign lamp)	10
2-c.p. carbon filament (sign lamp)	10

These data indicate that if an opaque screen were used an arc lamp with an opal globe would receive an undue advantage in comparison with the same lamp equipped with a clear glass globe

Errors due both to opacity of the screen and to variations in the relation between its size and that of the light-source may be eliminated by substituting for the opaque screen one of a particular translucency. The correct translucency must be arrived at empirically. It varies with sphere-diameter and with the screen-location. When a screen of correct translucency is obtained, a lamp with distorted light-distribution as described above, will illuminate the window uniformly, irrespective of its orientation, and correct testing of lamps of different sizes may be made.

PRACTICAL OPERATION OF THE SPHERE.

In using the integrating sphere, entire reliance must be placed in the "substitution" method of photometry. If the "substitution" method could be followed implicitly, the dimensions screening, etc. could be varied with impunity. Correct design becomes most important as lamps which are to be tested vary in type, size and distribution characteristics. Substantially correct results could probably be obtained from an inaccurate sphere if standard lamps whose total light-flux had been determined by other approved methods were available in sizes and types similar to those which were to be submitted to test. As, however, it is not practicable to keep available a large supply of standardized lamps of various sizes and types, correct design is imperative. Fortunately this result is attainable with much less difficulty than that experienced with almost any other photometric appliance. In even the smallest spheres with which the authors have had experience, after a proper screen had been found, little difficulty has been encountered in determining the mean spherical candle-power or total light-flux of any of the varied shapes of filaments encountered when the sphere had been standardized by a lamp of any particular filament shape; that is to say, even in a sphere so small as 11 inches in diameter, when correctly designed, the brightness of the window has been found to be independent of such differences in light-distribution as are met with in practice. If, however, it is desired to test frosted lamps in one of the smaller spheres, then standard frosted lamps must be provided. If it is desired to test lamps having discolored bulbs, standardized lamps in like condition must be used. If this is not done a slight error may be encountered. This error becomes negligible in spheres 18 inches in diameter and larger.

The integrating sphere may be used in conjunction with existing photometric apparatus. At the Electrical Testing Laboratories an 11-in. sphere has been used with small lamps, being placed immediately over the lamp mounted in the rotator of the ordinary photometer. The small translucent glass window in this sphere serves as the light-source, the illumination produced by it being compared by means of a Lummer-Brodhun contrast photometer with that produced by a comparison lamp at the other end of the bar, five meters distant.

The 30-in. sphere illustrated in Fig. 3, is used with a simple Lummer-Brodhun photometer, the photometric comparison being made by moving the comparison lamp back and forth in the horizontal box shown in Fig. 3. The same sphere has been used also in connection with a bar photometer and Lummer-Brodhun box into which was fitted a mirror at such an angle that the translucent window of the sphere was seen when looking into the eyepiece. The photometer box was otherwise undisturbed. Settings were made by varying the distance of the comparison lamp. Thus the brightness of the window was directly compared with the illumination produced on the photometer screen by the comparison lamp. The 18-in. sphere and the 80-in. sphere illustrated in Figs. 2 and 4 respectively, are used with a convenient type of portable photometer.

ADVANTAGES OF THE SPHERE.

In practice, the integrating sphere has been found to be a very practical device, possessing the following advantageous features:

Simplicity of Construction. The parts are few and easily built. There is an entire freedom from the complication which has been the blight of other integrating photometers.

No adjustment of parts necessary. A sphere, when correctly designed, needs no adjustment. The only thing likely to change is the character of the interior surface, the coating of which may have to be renewed from time to time. The only attention required is occasional cleaning to prevent dust from destroying the surface for photometric purposes.

Absence of flicker due to rotation of lamp. This fact means higher precision and higher speed in photometric settings.

Greater facility in arc lamp tests. Since the total flux of light is utilized in the integration, all effects due to the wandering of the arc are minimized.

Elimination of breakage due to rotation of lamp. A very important item, as those who have conducted tests upon metallic filament lamps can attest.

May be used in a light room where necessary. This fact renders the use of the sphere practicable where other photometers could not be employed because suitable dark rooms are not to be had.

Higher accuracy than other integrating photometers. A number of causes contribute to this greater accuracy. It is superior to photometers of the Matthews type in that it gives a true integration of the light rather than a summation. All values of the luminous intensity of the lamp are taken account of, while in the Matthews type some important values may be omitted altogether and have no influence on the result An example of this advantage has been seen in tests of magnetite arc lamps.

In the apparatus which has been used in the Electrical Testing Laboratories to determine light distribution about arc lamps, mirrors are located at intervals of 15 degrees, one being at the horizontal and another 15 degrees below the horizontal. The distribution curve of the magnetite lamp is characterized by a lobe between these two points. To determine this distribution properly for purposes of integration, the region between these two mirrors must be explored by other means. No difficulties of this kind are encountered in the integrating sphere. A second advantage arises from the fact that a single setting integrates the light distributed in all directions rather than throughout some particular azmuth, as is the case with most other integrating photometers.

The need for a practical apparatus for the determination of total light-flux has been emphasized of late years by the advent of many and varied forms of illuminants and by the impetus given to the study of light-sources and illumination as a result of the movement which culminated in the formation of the Illuminating Engineering Society. The comparison of different light-sources which has become most necessary and desirable in late years can be made with the closest approach to fairness, principally through a consideration of the total light-flux in terms of which best statements of lamp efficiencies can be made. The study of illuminating efficiencies is best facilitated through consideration of the light-flux. This involves a statement of the total light-flux of sources. Thus the study of both the production and the utilization of light is creating a demand for a simple means of determining light-flux.This means appears to be available in the integrating sphere.

DISCUSSION.

Mr. Francis E. Cady:—Has any investigation been made of the effect of the collection of dust or dirt on the inside of the sphere on the diffusing surface?

Mr. H. Thurston Owens:—Have the spheres been used in the photometry of gas lamps, such as gas clusters?

Mr. Alfred A. Wohlauer:—Can the theory of the integrating sphere be applied to the pre-calculation of the illumination due to reflection from walls and ceilings? Imagine a plane of 1,000 sq. feet illuminated by 160 mean spherical candles, and imagine furthermore this area bent into a sphere of equal areal contents and coated with a white diffusing paint. To what an extent would the illumination of this area be altered in such a case. There is reflection from walls, ceiling and floor and I imagine that the factors which are produced in the measurements with the sphere ought to be of interest in this case also.

Dr. Clayton H. Sharp:—In answer to Mr. Cady's question, as to dust, I really think the thing to do is to take the dust off. That is what we have done, and so have not made a study of the influence of dust on the sphere. I do not think dust would ordinarily affect the readings a great deal, because one must use the substitution method in any event.

The photometering of large gas lamps, is undoubtedly entirely feasible. The large sphere which is shown in the paper, has an opening at the bottom, with a detachable cover so that a good circulation of air can be obtained, so that a large gas cluster or anything of that kind can be used inside the sphere without causing any trouble at all. Of course, the sphere must be calibrated with the gas cluster in place, and with the cover to the lower opening removed, and with some protection against outside light entering at this point. With these precautions, there is no reason why the sphere should not be used for this purpose.

There is a constant to each sphere, but I do not quite see the direct connection between that fact and the measurement of light reflected from walls and ceilings. Undoubtedly as mentioned by Mr. Wohlauer there is a constant to reach room, as Messrs. Lansingh and Rolph have determined, and in that way

they are similar, but, of course, the constants are used in an entirely different way.

Mr. Carl Hering:—(Communicated after adjournment). The integrating sphere for measuring the spherical candle-power or the total flux, by means of one measurement, has been known abroad for some time, but seems not to have been satisfactory. It would therefore be interesting to know in what particulars the one described in this paper differs from the original form; and how the objections to the latter have been overcome.

If it measures the total flux or mean spherical candle-power correctly, then it must, of course, give a constant reading if the lamp were replaced by a small search lamp which throws out all the light in one small intense beam, and if this beam be directed to different parts of the sphere. It would be interesting to know what the results of this rather severe test would be. From my examination of the apparatus exhibited, I should expect the error to be great when such a beam is directed to the surface near the test screen, as the latter was recessed about 1/16 in. behind the surface of the sphere, which would shield it from quite a large part of this sphere near it. Moreover, the translucent screen, which shields the test screen from the direct rays, casts a large and decided shadow on the spherical surface. As I understand it, theory would require that this should not cast a shadow when it is made as large as it is.

In view of Dr. Sharp's criticism of a paper which I read at the Convention, it is of interest to note that in his paper on this sphere, he, himself, several times uses the terms "mean spherical candle-power" and "total luminous flux" synonymously, as representing the same thing except as to a coefficient; and as it is well known that a coefficient cannot change the physical nature of a quantity, he, himself, considers these two quantities to be physically the same.

Dr. Clayton H. Sharp:—(By letter). Mr. Hering assumes that the sphere in foreign practice has proven unsatisfactory. He should give his reasons for such assumption. The authors have quite the contrary impression which has been so strong that we have considered that this type of integrator merited being brought more directly to the attention of photometrists in this country than has previously been done. The spheres with which we have

worked do not differ at all in principle from those which have been used abroad: only the details of arrangement are different. Moreover they are satisfactory integrators and convenient arrangements.

The search-lamp test which Mr. Hering proposes would be a most severe one and would undoubtedly reveal an inaccuracy of any sphere, since the integration is not perfect in any one, due to causes outlined in the paper. The authors have contented themselves with tests of a less academic character designed to bring out the qualities of the sphere under conditions more approximating those of actual practice.

Mr. Hering has fallen into the error of confusing the apparatus exhibited with that on which our experiments were made. The latter may have mechanical shortcomings which the manufactures have not as yet corrected and it has not as yet been tested photometrically. As to the interesting shadow which Mr. Hering finds I am moved to remark that the real object of the screen is to cast a shadow. Mr. Hering will doubtless find a more careful study of the theory of the sphere enlightening on this point.

In the conclusion to his discussion Mr. Hering takes occasion to refer to some remarks made by myself in the course of a discussion of his paper. He here gives the coup de grace to the same man of straw which he spent so much energy in demolishing in his reply to my discussion of his paper. He assumes that I said that the "spherical candle" could not be used as a unit of flux, and he seeks laboriously to prove my error. As a matter of fact I said that we can make the unit of flux one spherical candle. My contentions were that it had never been done until Mr. Hering did it and that since such a unit is unnecessary, superfluous and at variance with the established system of units, its introduction serves no good purpose and is in direct opposition to the expressed design of Mr. Hering's paper, namely the clarifying of our ideas in regard to the nature and interrellations of the photometric units. Moreover, most of these contentions, I think, Mr. Hering in his reply to my remarks has admitted to be true.

THE CALCULATION OF ILLUMINATION BY THE FLUX OF LIGHT METHOD[1]

BY J. R. CRAVATH AND V. R. LANSINGH.

It is the object of this paper to give certain methods employed by the authors for a number of months past in calculating the illumination of large interiors and to show the practical application of the excellent suggestions made by Dr. Clayton H. Sharp in his presidential address before the first annual convention of the Illuminating Engineering Society at Boston July 30, 1907. The authors expressed the opinion at that time that the simple methods suggested by Dr. Sharp would be of considerable practical value, and immediately upon the close of the convention worked out methods of applying them in every-day engineering practice.

In this paper no attempt will be made to describe in detail the methods of calculating illumination which were common previous to the time Dr. Sharp delivered his address, and which are now generally used. The most common method where accurate calculations were made was to plot a rectangular curve of illumination with the polar photometric curve of a single lamp as a basis. If there were a number of sources of light in a room the distance of each from any given point was determined, preferably by a drawing made to scale. By adding together the illumination obtained from the various sources the total illumination on any one point could be found. This point-by-point method has been fully described in Chapter IV of "Practical Illumination," by the authors, and in other engineering literature. Its principal drawback is the amount of labor involved. It may be in order here to call attention to an error of application which has frequently crept into calculations by the point-by-point method and also into actual measurements. To approximate the true average illumination on a working plane, one must select a sufficient number of points equally spaced over the entire plane. The illumination must be calculated or measured for all these

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

points. For example, in Fig. 1, suppose the source of light to be hung over the middle of the center circular area A. Assume the illumination of area A to be 4 foot-candles, B 3 foot-candles, C 2 foot-candles, and D 1 foot-candle. The incorrect method frequently used is to take the average of these, or 2.5 foot candles, as the average of the whole area. The correct method is to multiply the illumination by the area covered and take the mean of these results; or, in other words, to obtain the weighted mean

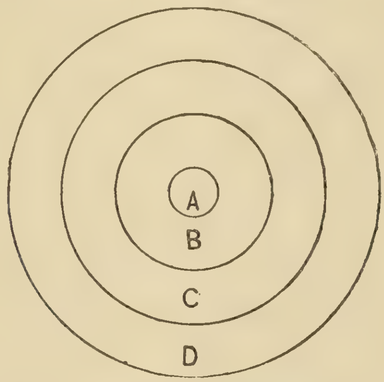


Fig. 1.—Diagram of Concrete Areas.

of the various circles. Let the diameter of A=1, B=3, C=5 and D=7.

$$\text{Then the area } A = \frac{\pi}{4} 1^2 = \frac{\pi}{4} 1$$

$$B = \frac{\pi}{4} (3^2 - 1^2) = \frac{\pi}{4} 8$$

$$C = \frac{\pi}{4} (5^2 - 3^2) = \frac{\pi}{4} 16$$

$$D = \frac{\pi}{4} (7^2 - 5^2) = \frac{\pi}{4} 24.$$

The weighted mean of the illumination will then be

$$\frac{\frac{\pi}{4}\left[(1\times 4 \text{ ft.-candles})+(8\times 3 \text{ ft.-candles})+(16\times 2 \text{ ft.-candles})+(24\times 1 \text{ ft.-candles})\right]}{\frac{\pi}{4} 49} = 1.72.$$

The true average is therefore 1.72 foot-candles instead of 2.5 foot-candles.

The suggestion advanced by Dr. Sharp was to the effect that the total amount or flux of light given out from the lamps be calculated in lumens to determine the amount of light available, and that the average intensity of illumination in foot-candles on

the working plane it is desired to illuminate be determined from the number of lumens falling on that plane.

The lumen, according to English standards, may be defined as the amount of light falling on a surface 1 ft. square, when it is evenly illuminated to an intensity of 1 foot-candle. Thus, if a source of light giving 1 candle power in all directions be placed in the center of a sphere of 1 ft. radius, each square foot surface of that sphere would receive one lumen; and since the surface of a sphere is 4π, or 12.57, times the square of the radius, a sphere of 1 ft. radius will have a surface of 12.57 sq. ft. A lamp of 1 mean spherical candle power illuminating 12.57 sq. ft. with an illumination of 1 foot-candle would, therefore, be giving out 12.57 lumens. The number of lumens given out by a lamp is, therefore, the mean spherical candle power multiplied by 12.57. In illuminating engineering calculations one is concerned principally with the flux of light or in other words with the number of these lumens which fall upon a certain plane commonly referred to as the working plane. For example, in a large store, the working plane would be considered as being even with the tops of the counters, or about 42 ins. from the floor. In a large general office room it would be the plane of the desk tops, about 30 in. from the floor.

It is desired to determine as accurately as possible in advance the average illumination in foot-candles which will be obtained on the working plane. The lumen being that flux of light which will produce an average illumination of 1 foot-candle over a surface of 1 ft. square, it easily follows that if the total number of lumens emanating in the direction of the working plane and the number of square feet in the plane are known, we can easily arrive at the average foot-candle intensity by dividing the total number of lumens by the square feet in the room or plane. Thus, if there are 300 lumens falling on a plane of 100 sq. ft. area there is an average intensity of 3 foot-candles over that plane.

To make practical application of these principles in the calculation of illumination, it is necessary to determine with approximate accuracy the number of lumens given out from the lamps in the direction of the plane to be illuminated. When this is determined it is then necessary only to add together the number of lumens directed toward the working plane by all of the

lamps in a room and to divide this total by the number of square feet in the room to get the average foot-candles on the working plane.

This method, of course, takes no account of the lumens directed toward the ceiling and walls, a part of which ultimately reach the working plane by reflection. This element of uncertainty, however, is the same as that which accompanies other methods of calculation heretofore used. Of course, in the majority of cases a certain proportion of the total number of lumens given out by the lamps is needed to illuminate ceilings and walls. Except where opaque reflectors are used, this portion of the problem can usually be neglected, bcause the ordinary opal, prismatic and sand-blasted reflectors let through enough of the total lumens given out by a lamp to take care of ceiling and wall illumination.

This method further takes no account of the variations between maximum and minimum illumination which may exist in different parts of a room. If there is any question as to whether the illumination will be uniform enough for practical purposes, this method should be supplemented by the older point-by-point method before referred to, in order that the probable variations between maximum and minimum can be determined. This method, however, is most generally applicable to large interiors with many lamps, these lamps being spaced at sufficiently short distances so that the variations in illumination are not great. In a large low room with a few very large sources of light, this method would not be of much value. Fortunately the number of rooms lighted in this way is on the decrease.

With this method it is evident that the key to the problem is the determination of the probable number of lumens directed toward the working plane. To do this with accuracy for all the lamps in a room would be a mathematical task out of the question for common engineering work. It is possible, however, to make some assumptions which are approximately correct and which render the calculation very simple.

For example, in the lighting of a large store or general office room, calculations seem to show that one may consider as effective all the lumens given out from a lamp within an angle of about 75 degrees from vertical. In the case of lamps located

near the walls this relation will not be strictly true because of the lumens which will first strike the walls. Some of these, of course, will be recovered by reflection. In smaller rooms where lamps are placed close to walls, the lumens falling within 60 degrees of a vertical line through the lamp may be assumed as striking the working plane. The accuracy of these assumptions will be discussed later in the paper.

It is well to describe rapid methods for determining the number of lumens given out in different zones about a lamp. Assuming that the distribution of light about each lamp is practically symmetrical with reference to the axis of the lamp and that the lamps are to be placed with axes vertical (these being the conditions now commonly prevailing with high candle-power incandescent lamps, Nernst lamps and arc lamps) it is very easy to determine the number of lumens given out within a certain number of degrees from the lamp axis or perpendicular. One of the quick ways to determine the lumens is to plot a Rousseau diagram. It will not be necessary here to discuss the principle of the Rousseau diagram, as it has been described in a number of works dealing with photometry, and in the paper by Mr. J. E. Woodwell, printed in the TRANSACTIONS of the Illuminating Engineering Society, Nov., 1906, Page 248. It will be sufficient here to explain that it is a curve, Fig. 2, the height of which at any point represents the candle-power at the angle corresponding to that point and the area of which is proportional to the flux of light or lumens from the lamp.

The method of preparing Rousseau diagram paper is also indicated by Fig. 2, in which the full lines represent the preferable Rousseau diagram ruling and the dotted lines indicate the method by which the ruling is obtained. Rousseau diagram paper already ruled is now easily obtainable. In Fig. 2 is shown a Rousseau curve plotted for a Gem lamp of 50 mean horizontal candle-power in a prismatic bowl reflector. The polar-co-ordinate candle-power curve, commonly known as the photometric curve of the same lighting unit is also shown in Fig. 2. The method of plotting the Rousseau illumination curve from the polar candle-power curve will be apparent upon brief inspection. For example, looking on the polar photometric curve, it is seen that the candle-power at ten degrees from the vertical is 65. A dot

should be placed on the ten-degree line of the Rousseau diagram at the height 65 corresponding to the candle-power. At 20 degrees from the vertical the candle-power shown on the photometric curve is 80; a dot should be placed on the 20-degree vertical line of the Rousseau diagram at a height corresponding to

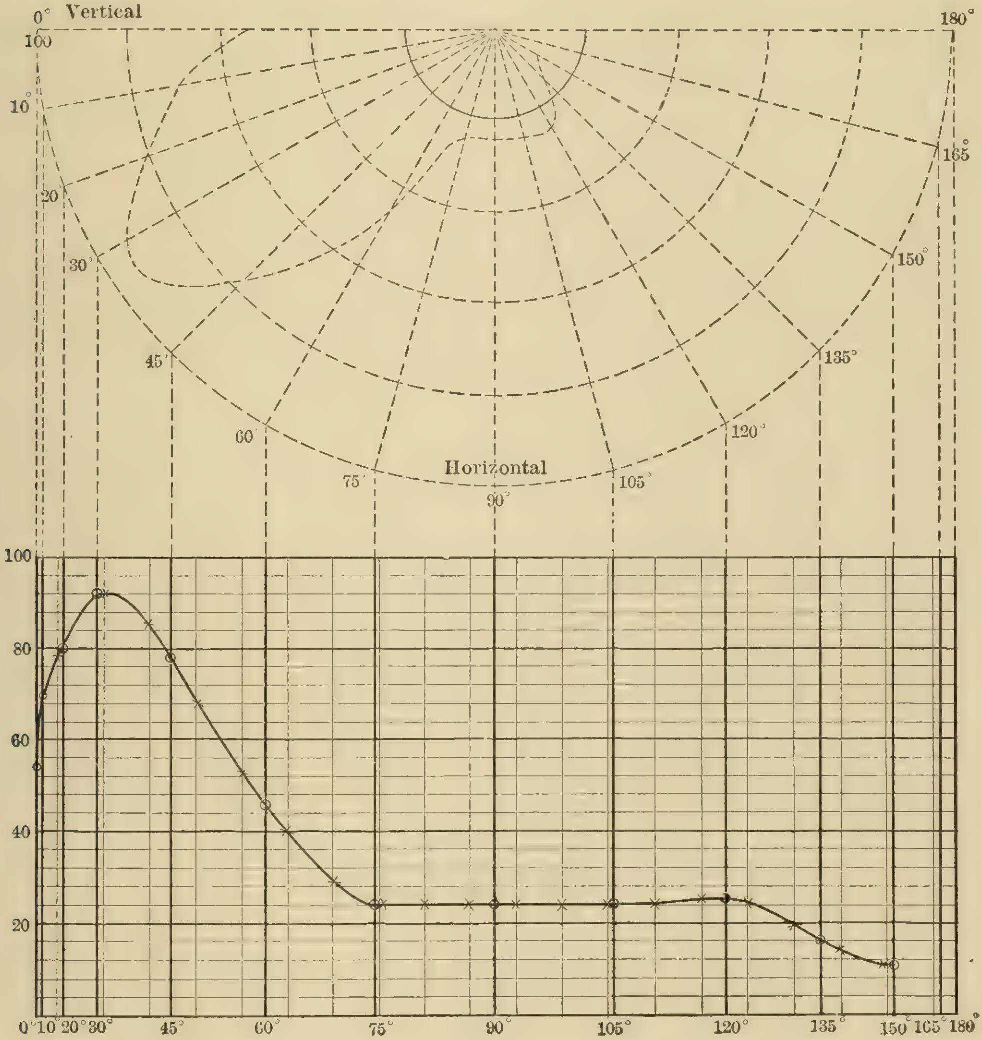


Fig. 2.—Rousseau Diagram for Gem Lamp with Bowl Reflector.

80 candle-power. When this has been done for the entire half circle, these dots should be joined to form the curve called the Rousseau curve or diagram. The area of this diagram between any two vertical lines representing degrees corresponds to the total flux of light in lumens given out in the zone bounded by those degrees. For example, the area enclosed by the curve between zero and 90 degrees (90 degrees being horizontal) repre-

sents graphically the number of lumens given out in the lower hemisphere; while the area enclosed by the whole curve from zero to 180 degrees represents the total number of lumens given out. If the average height of this curve be found by measuring its height at equal intervals one obtains the mean spherical candle-power. To determine the number of lumens from the Rousseau diagram it is necessary only to ascertain the area enclosed by the curve expressed in proper terms. In the Rousseau curve shown in Fig. 2, the ruling is such that there are twenty equal divisions of the diagram as measured horizontally. As the average height of the curve represents candle-power, the horizontal distance instead of 20 should be 12.57, if the area is to represent lumens. The constant by which the sum of the candle-power readings must be multiplied in order to get the lumens in this case is therefore, $\frac{12.57}{20}$, or 0.628.

Another and preferable method of determining the number of lumens in any given zone is to measure the average height of the curve within that zone, which height gives the mean zonular candle-power. Multiplying this mean zonular candle-power by a certain factor which may be called a flux factor, will give the number of lumens within that zone. This flux factor is the area of the zone of a sphere of unit radius. Since the flux in lumens is equal to the area in square feet multiplied by the mean foot-candle intensity, and since 1 foot-candle intensity will be given anywhere on the inner surface of a sphere 1 ft. in radius by a light of 1 candle-power, the area of the zone of a sphere need merely be multiplied by the mean zonular candle-power to determine the lumens within that zone. The area of the zone of a sphere of unit radius equals $2\pi\ (1 - \cos a)$ where a equals the angle between the pole or vertical and the edge of the zone. The flux factors calculated by this formula for angles from 5 to 90 degrees are as follows:

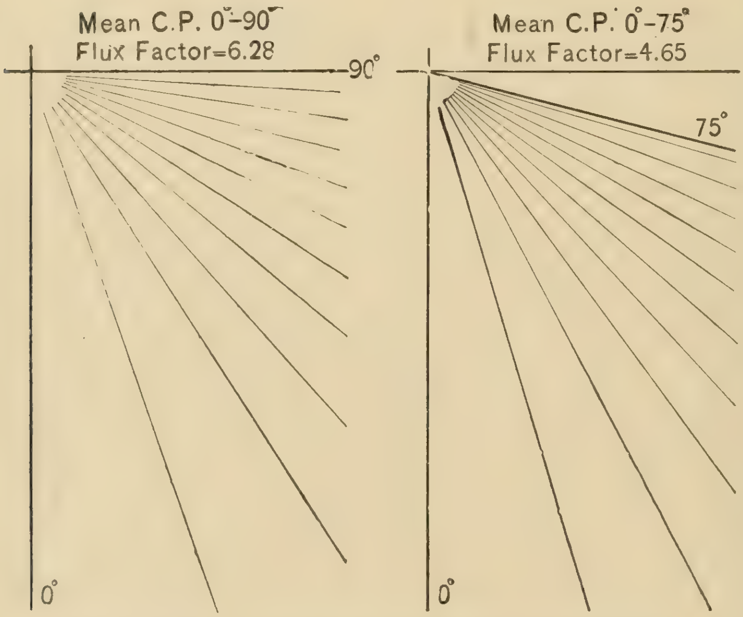
Degrees	Flux factor
5	0.025
10	0.094
15	0.0220
20	0.376
25	0.590
30	0.842

Degrees	Flux factor
35	1.13
40	1.47
45	1.84
50	2.24
55	2.68
60	3.14
65	3.62
70	4.18
75	4.65
80	5.18
85	5.73
90	6.28

The above considerations lead to a further short cut which obviates the necessity of plotting a Rousseau curve. From a study of Fig. 2, it will be evident that from the polar curve one can obtain the candle-power values for the points indicated by crosses on the Rousseau curve if the radial lines on the polar curve correspond in position to the fine equally-spaced lines of the Rousseau curve. It is a simple matter of drafting to provide a set of flux polar diagrams with radial lines corresponding to the positions of the equally-spaced lines on the Rousseau diagram. Such a flux polar diagram for an angle of 90 degrees is shown in Fig. 3. If this diagram is made on transparent celluloid or tracing cloth, it can be laid over the ordinary polar-photometric curve with the zero line at the vertical and the 90-degree line at the horizontal. By noting and averaging the candle-power of the photometric curve at the ten points where the radial lines (not including the zero and 90-degree lines) cross the photometric curve, the mean hemispherical candle-power is obtained. As there are ten readings to be averaged, it is only necessary to add the readings and transfer the decimal point one figure to the left to obtain the average. This mean value of hemispherical candle-power multiplied by the flux factor 6.28 for the 90-degree zone, gives the total number of lumens in the lower hemisphere. Similar flux polar diagrams can be prepared for other zones. For example, Fig. 4 is arranged for obtaining the mean zonular candle-power and lumens in a zone extending 75 degrees from the vertical. This diagram also is divided into ten parts so that the average of the readings is obtained by dividing their sum by 10 and the lumens are obtained by multiply-

ing this average by the flux factor 4.65 for 75 degrees. The same thing is true of Figs. 5 and 6 which are for 60 and 30 degrees, respectively. With a set of these flux polar diagrams, the illuminating engineer is in a position very quickly to find the lumens from any symmetrical photometric curve within any of the zones which are of practical use to him.

To show the practical application of the above described method, on applying the 60-degree flux polar diagram to the polar photometric curve shown in Fig. 2, it is found that 236 lumens are given out by the lamp between 60 degrees and the vertical.

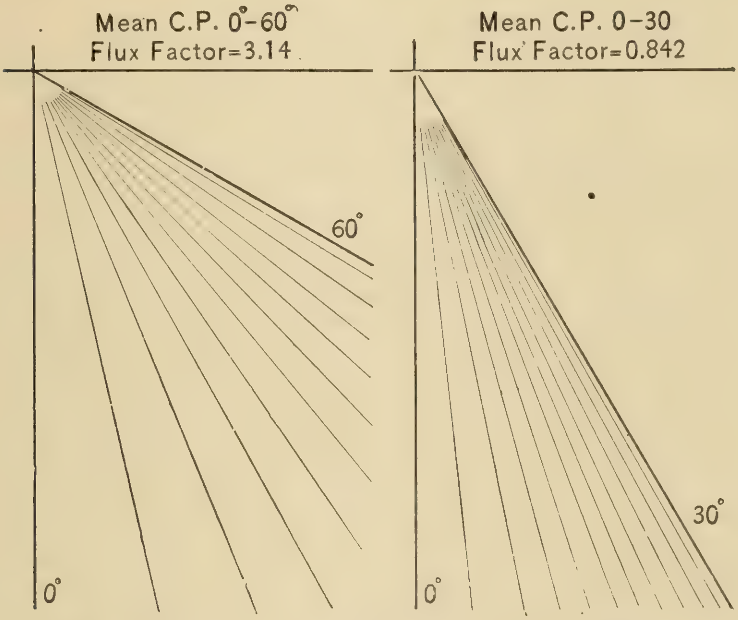


Figs. 3 and 4.—Flux Polar Diagrams, 90 and 75 Degrees.

The curve of Fig. 2 relates to a 125-watt Gem lamp in a bowl reflector, so the value for lumens can be reduced to watts per lumen by dividing the wattage of the lamp; thus there is 0.53 watt per lumen. Therefore, if 0.53 watt is expended per square foot of floor space, one lumen per square foot is obtained. Since the average intensity in foot-candles is equal to the lumens divided by the square feet and the area in this case is 1 sq. ft., the average foot-candle value will be 1. In other words, if the average foot-candle intensity be multiplied by the value of watts per lumen in the zone under consideration, obtained with the desired lamp and reflector, the value of the watts per square foot

necessary to illuminate the room will be obtained. The rule or formula then simply becomes:

Average foot-candles $\times$ watts per lumen $=$ watts per sq. ft.



Figs. 5 and 6.—Flux Polar Diagrams, 60 and 30 Degrees.

It now remains to determine how closely the results calculated as above check with actual results obtained in installations which have been photometered. It is evident that the main chances of error in the above method lie in the reflection from walls and in assuming too large or too small an angle from the vertical in which to determine the flux of useful light. In a small room with very dark walls and the lamps placed high, the zone of useful light as measured by the angle from the vertical would be small, sometimes not over 50 or 60 degrees. On the other hand, in a very large room with few obstructions and with light-colored walls, the light which emanates from the source at a considerable angle from the vertical ultimately falls on the working plane and becomes useful. The area illuminated by each lamp is very large in such a case and each point in the working plane receives illumination from many lamps.

There is given herewith a table of constants based on all of the results of reliable tests on efficiency of illumination which have come to the notice of the authors. This table is the result

of careful consideration of all the evidence obtainable, and is believed to be approximately correct. The table shows the watts per lumen, or in other words, the watts per square foot required to give one foot-candle average illumination in several types of lighting installations.

To apply it use the rule.

Watts per sq. ft. = foot-candle intensity × constant from table.

TABLE SHOWING NUMBER OF WATTS PER SQUARE FOOT OF FLOOR AREA REQUIRED TO PRODUCE AN AVERAGE OF 1 FOOT-CANDLE OF ILLUMINATION. (WATTS PER LUMEN.)

Incandescent Lamps.	
Tungsten lamps rated at 1.25 watts per horizontal candle power; clear prismatic reflectors, either bowl or concentrating; large room; light ceiling; dark walls; lamps pendant; height from 8 to 15 feet	0.25
Same with very light walls	0.20
Tungsten lamps rated at 1.25 watts per horizontal candle power; prismatic bowl reflectors enameled; large room; light ceiling; dark walls; lamps pendant, height from 8 to 15 feet	0.29
Same with very light walls	0.23
Gem lamps rated at 2.5 watts per horizontal candle power; clear prismatic reflectors either concentrating or bowl; large room; light ceiling; dark walls; lamps pendant; height from 8 to 15 feet	0.55
Same with very light walls	0.45
Carbon filament lamps rated at 3.1 watts per horizontal candle power; clear prismatic reflectors either bowl or concentrating; light ceiling; dark walls; large room; lamps pendant; height from 8 to 15 feet	0.65
Same with very light walls	0.55
Bare carbon filament lamps rated at 3.1 watts per horizontal candle power; no reflectors; large room; very light ceiling and walls; height from 10 to 14 feet	0.75 to 1.5
Same; small room; medium walls	1.25 to 2.0
Carbon filament lamps rated at 3.1 watts per horizontal candle power; opal dome or opal cone reflectors; light ceiling; dark walls; large room; lamps pendant; height from 8 to 15 feet	0.70
Same with light walls	0.60
Arc Lamps.	
5-ampere, enclosed, direct-current arc on 110-volt circuit; clear inner, opal outer globe; no reflector; large room; light ceiling; medium walls; height from 9 to 14 feet	0.50

It is interesting to compare the results shown in the table with the results which would be obtained in the calculation of the illumination of similar interiors by the flux-of-light method which is described herein. For example, taking the first two items on

the table, the constant obtained from practical experience is 0.20 to 0.25 while the calculated flux of light from tungsten lamps with bowl reflectors within 75 degrees from the vertical corresponds to about 0.20 watt per lumen. The calculated flux within 60 degrees corresponds to 0.23 watt per lumen. For this item it would seem that the zone of 75 degrees is the one which gives the most accurate results with light walls while the 60-degree zone would be best for dark walls. Referring to the seventh item on the table, by calculation carbon-filament lamps with bowl prismatic reflectors, take 0.495 watt per lumen below 75 degrees and 0.63 watt per lumen below 60 degrees. The table gives 0.65 watt per lumen. For conservative estimates the 60-degree zone should usually be taken.

The methods described above are only approximate at best, but probably they are no more open to error than other methods. They are certainly much more simple and rapid. The authors have used them for the past year.

DISCUSSION.

Mr. R. L. Lloyd:—The authors conclude their paper with a paragraph beginning as follows:

"The methods described above are only approximate at best."

I am a member of this Society, not as a scientist or investigator, but as one who wants some practical facts to work on. Probably there are many others who are in the same boat as myself, and to show how very practical the tables really are, a little experience of mine cannot be amiss. Out in the burgh, where I live, we have recently attained the dignity of a concert hall, called an auditorium. Naturally, I was interested at the start in the project, and as soon as I was able got hold of the plans looked into the arrangements for the lighting. To my mind, they were very meagre and insufficient, and after talking the matter over with those in charge, I volunteered to lay out a lighting plan for them.

I did not know much about the matter, but had entire confidence in the tables and formulae which I gathered from our Society. With these as a basis, I recommended six tungsten lamps in the ceiling, (the ceiling probably a little higher than in this room—about 25 feet)—which should give about one candle-power per

square foot of illumination over the main floor. The committee accepted my suggestion, and had the building so wired. When finished and the time came for turning them on, I felt somewhat shaky to think that the few lamps were going to do the work, but they did it admirably and the hall was well lighted with a smaller power consumption than originally planned. I give credit for it entirely to the tables followed, the tables produced by members of this Society.

President Bell :—That is an illustration of the practical nature of the work which the Society is doing.

Mr. J. S. Codman, Boston :—The table given is somewhat interesting. In comparing the first item, tungsten lamp rated at 1.25 watts per horizontal candle-power, with Gem lamps at 2.5 watts, conditions in the two cases seem to have been precisely the same. According to the ratings, the tungsten lamp has double the efficiency of the Gem, yet it appears that, instead of the watts per square foot in the case of the Gem being just double, it is merely slightly greater.

Further than this, the actual efficiency in the tungsten lamp is not double that of the Gem, if account be taken of the spherical candle-power. If the spherical reduction factor of the Gem can be assumed as 0.85 and that of the tungsten 0.79, it would seem that the tungsten has an efficiency only 1.86 times that of the Gem. In such case, the watts per square foot for the Gem calculated on the basis of the relative efficiencies should be 0.46 instead of 0.55. In other words, the tungsten lamp as compared with the Gem, gives very much better results than would be expected from its efficiency.

There are one or two possible explanations of this fact. In the first place, it is possible that in the tungsten installations which were tested, the illuminating engineering work was better than in the case of the Gem, or it may be that the Gem installations were older and the candle-power of the lamps had decreased. The tungsten lamp installations would probably be the more recent.

There is another possible explanation, which occurred to me, namely that the tungsten lamp being whiter, in the majority of cases, the reflection from the walls would be higher with the white light. For instance, if the walls were red, the reflection of

the walls would be higher with the white tungsten than with the yellow Gem.

Mr. T. W. Rolph:—In connection with Figs. 3, 4, 5, and 6, I have here a table of the calculated values of the angles at which readings should be taken in order to obtain the mean candle-power of these various zones, and feeling that this might be of interest, I submit it for reference. It is as follows:

ANGLES FOR TAKING 10 READINGS IN THE DETERMINATION OF MEAN CANDLE-POWER MEASURED FROM THE VERTICAL.

	0°—90°	0°—75°	0°—60°	0°—45°	0°—30°
1	18°—12′	15°—39′	12°—50′	9°—49′	6°—38′
2	31°—47′	27°—17′	22°—20′	17°—2′	11°—30′
3	41°—25′	35°—27′	28°—57′	22°—4′	14°—53′
4	49°—28′	42°—13′	34°—25′	26°—10′	17°—37′
5	56°—38′	48°—12′	39°—11′	29°—45′	20°—0′
6	63°—15′	53°—41′	43°—32′	32°—58′	22°—8′
7	69°—31′	58°—47′	47°—33′	35°—56′	24°—6′
8	75°—31′	63°—38′	51°—19′	38°—42′	25°—54′
9	81°—22′	68°—17′	54°—54′	41°—19′	27°—37′
10	87°—8′	72°—48′	58°—20′	43°—48′	29°—13′

Mr. Alfred A. Wohlauer:—The paper marks further attempts to simplify the pre-calculation of illuminations in a strictly engineering manner. It is necessary, however, to recognize that the amount of flux which is utilized for illumination, and the amount of light which is reflected from walls and ceilings, must be strictly kept apart. I believe that I can explain by consideration of this fact the doubt Mr. Codman expressed in regard to the discrepancy in the data given for the tungsten lamp and for the Gem lamp.

On the one hand, the reflection from wall and ceiling is different in the two cases, and on the other hand the solid angle which is utilized for the light production varies according to the light distribution of the lamps employed. As far as the experimental values recorded in the table are concerned, I may say that they are of about the same order as some constants I published several months ago, leaving reflection from the wall and ceiling entirely out of consideration.

Mr. P. S. Millar:—The authors have applied Dr. Sharp's suggestion of last year in an interesting and practical manner. The way in which it has simplified calculations of illumination is remarkable, and it seems to me that it marks a step in advance, by making the calculation of illumination something no longer to be feared.

In connection with this matter, I call attention to the desira-

bility of collecting and tabulating data bearing upon the coefficient of utilization of light—another suggestion made by Dr. Sharp in his presidential address last year. This is a valuable factor and would still further simplify the estimation and calculation of illumination if reliable data could be furnished.

Mr. V. R. Lansingh :—There was one suggestion made by Dr. Sharp which I want to accept, and which has not been done in this paper. We have used here the term watts per lumen, whereas a better relation would be lumens per watt. I hope in general that this practice will be revised and that in speaking of the performance of a Gem illuminant use will be made of the term lumens per watt rather than watts per lumen.

As to Mr. Codman's question concerning the apparent discrepancy in the data of the Gem lamp and of the tungsten it should be stated that the Gem lamp tests were inconsistent. We had values all the way from the figures given by Mr. Codman, 0.45 up to and over 0.60, and we took 0.55 as a possible mean. As to what the cause of that is, I cannot state. It may be due to the defects in the lamp itself, and also to its color value. The Gem lamps do not always run as they are rated. These figures given here are the mean of all the observations which we could accumulate. One of the chief sources of these figures were the tests made for the Association of Edison Illuminating Companies at the Edison Auditorium by the Electrical Testing Laboratories in New York.

As regards the question of Mr. Wohlauer, concerning reflection from ceilings, I should state that the data given in the paper take reflection into account. They are not theoretical values but practical values obtained from actual tests. It is interesting to note that these figures check up very closely with the theoretical considerations.

Mr. F. W. Willcox :—The reason why the practice has always been to speak of "watt per candle" seems to me to be a practical one, namely, that we then deal with integral units, 3.1, 3.5, 4, 2.5, or 1.5, or whatever the specific consumption may be, in the Gem lamp 2.5, and in the tungsten 1.25. If we use this reciprocal term, we will have a fraction, and the difference between 3.1 and 3.5 would not be as apparent in fractional form as in integral form.

Applying the same idea to Mr. Lansingh's suggestion, it would be better to use the term "lumens per watt" than "watts per lumen," as the former would give a whole number and the latter a fraction.

STREET LIGHTING WITH GAS IN EUROPE.[1]

BY E. N. WRIGHTINGTON

Gas is used for street lighting in the Continental European cities in many forms. Both inverted and upright mantles are used under ordinary and high-pressure. The low-pressure upright lamps comprise the principal lighting of the side streets. The high-pressure upright lamp is just coming into use for the lighting of the principal thoroughfares. The inverted lamp is, however, taking the place of the upright type. The low-pressure inverted lamps are used for ordinary illumination, and the high-pressure inverted lamps on the main streets.

The low pressure upright lamp is of the type familiar in America. One or more burners to the lamp are used. The lamps are placed rather nearer together than in this country, resulting in a good distribution of light, and the general illumination is very satisfactory. The high-pressure upright lamp is used for special lighting where large units are desirable. The efficiency is high as compared with the low-pressure lamp.

The inverted lamp for use on the streets seems to have been pretty thoroughly tested on the other side, and is giving good results. The efficiency for useful light obtained greatly exceeds that of the upright lamp. There are two reasons for this advantage. First, because the proportion of light below the horizontal—where it is wanted in street lighting—from a bare mantle of an inverted lamp is much greater than from an upright mantle. Second, because the construction of the inverted mantle burner permits the use of reflectors which will collect the upright rays and turns them in a useful direction. Most of these lamps are equipped with a pilot flame, and the main lamp is ignited by means of a lever arm. It is claimed that partly for this reason the number of mantles used is less than with the upright lamp.

Another advantage in the inverted lamp is that it lends itself to artistic treatment. A double-arm post with one lamp on each arm, and each lamp having two burners, produces a dignified

[1] A paper read at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

and handsome effect. This combination, the posts being set at intervals of 100 feet, staggered on each side of the street, also gave a very even and effective illumination.

The most striking feature of the street lighting on the other side is unquestionably the use of high-pressure inverted gas lamps. These lamps are found in very large units, running as high as 3600 mean lower hemispherical candle-power. The posts are placed near together, and the streets are almost as bright if lighted by daylight. One might expect to find the light rather glaring, especially as the lamps are hung rather low ; on the contrary, however, the light is beautifully diffused, the effect being very soft and pleasing.

From one to three mantles of large size are used for each lighting unit. These mantles are attached to the lamp non-collodionized. A by-pass is used, and the pressure, which amounts to about 60 inches, opens the valve, and the lamp is ignited. The mantles shrink to the proper size, and form naturally on the burner. At midnight one or more of the burners of each lamp may be extinguished by the turning of a lever arm, thus reducing the expense when less light is needed. These lamps seem to be very satisfactory in operation, and have been installed a number of months.

In considering these various types of street lighting, a very important difference between the conditions on the other side and in this country must be recognized. Wherever, in this country, there is a traffic at night which would require such a great quantity of light as exists on the other side, very little outside illumination is needed. Fortunately for some of the municipal authorities, the streets are lighted by private citizens by means of window lamps and signs. For example, along Broadway, in New York, the so-called street lamps are hardly necessary, and the light which they give is almost entirely overshadowed by the private lighting around them. Wherever there is traffic, there are window lamps and signs; or putting it the other way, the signs and window lamps attract the traffic.

In Continental cities, on the other hand, it is the rarest thing to find any windows lighted after dusk. The shutters are pulled down tight, and the lighting of the streets is dependent entirely upon the street lamps. Yet at the same time, a very great amount of light is needed, as the traffic both on foot and on wheels is very

heavy. For this reason where lamps of 3600 candle-power, 100 feet apart, may be necessary in Europe, it is probable that such a very large amount of light would not be needed except for special lighting in this country.

It is entirely reasonable, however, to expect that the small units, both under high-pressure and low-pressure, adjusted to suit local conditions, may be used in this country. The smaller inverted lamps are claimed to give on low-pressure an output of from 30 to 40 candle-power per cubic foot of gas consumed per hour, and on high-pressure from 50 to 60 candle-power. These lamps installed at intervals to afford a proper distribution of the light, should give a highly satisfactory illumination at a reasonable cost.

DISCUSSION.

Mr. Walton Forstall:—Can Mr. Ware tell us the usual pressure at which the gas is supplied? At the gas exhibition in Dublin, last year, 16-in. was used, and my impression has been that this was about the usual pressure, though I remember one installation using 60 in. Is the tendency toward the use of such high pressures? I should like to know the horizontal distance apart of the mantles on any post—the writer speaks of a separation of the mantles to prevent a glare. What is the height of the mantles above the ground?

President Bell:—The Chair perhaps can answer Mr. Forstall's questions, or some of them, from personal observations, which information may not be at hand elsewhere. The 60-inch pressure is the highest value that is now being used with the compressed gas. The pressure of compressed gas started a few years ago at 10, or 12, and then it went to 16, and then to 20, and to 30 or 40, and has now reached 60 inches, the exact pressure in the Berlin system, which is perhaps the best developed of any, being 12 centimeters of mercury. The distribution is through steel tubes, which are put together with gaskets. The lamps are supplied with gas by a pressure pumping station, operated by gas engines. In Berlin use is made of compressed gas, and that seems to be the more usual tendency, although some of the systems have used compressed air, and one of them, in Paris,

actually fed oxygen obtained from liquid air to the burner to intensify the light.

Mr. T. J. Litle, Jr.:—The scheme of compressed gas lighting is only in its infancy, and probably pressures even higher than stated will be used. Recently I experimented with gas under 71-in. of water pressure with a special mantle, with good results; this mantle has not yet appeared on the market. I think these changes will revolutionize the whole business, as far as high pressure lighting goes, and enable very high efficiency to be obtained.

In the paper no mention is made of the control of these lamps. In Europe use is made of many schemes in which there are two pressures, low pressure for supplying gas to the pilots during the day, the pressure at night being boosted in the line, the high pressure gas being admitted to the main burner, thereby enabling the whole system to be ignited and extinguished from a central point.

President Bell:—To remove a possible misapprehension, it should be stated that in the gas burners there is no enormous pressure at the point of combustion, the object of the pressure being mainly to inspirate a sufficient quantity of air to give an intensified flame. The high pressure does not operate against the mantle.

Mr. V. R. Lansingh:—I do not agree with the writer of the paper when he says that there is no glare to these lamps, at least in the City of London. My observation of the lamps in that city was that there was a great deal of glare from the high-pressure mantles, and that some method of diffusing the light is desirable. There seemed not to be as much glare in the case of the lamps in London as found in this country, due probably to the reflection of the buildings, but nevertheless, there is room for much improvement.

President Bell:—The glare from the high-pressure mantles is very severe, and the higher they are forced the more it is true. They give a very powerful, brilliant light, and should have diffusing globes. In London there are some self-intensifying lamps, generally worked by the waste heat from the burner. One type has even a flat thermopile surrounding the lamp, the current from which is conducted to a little electric motor in the base of

the lamp, which pumps up the pressure by a special blower. In another form there is a supplementary heater. There are three or four forms of the self-intensified lamp, but I think I am correct in saying that the tendency is toward separate mains for the high-pressures. I inquired of the men in charge of the lamps, and was informed that the life of the thermopile was about 1,000 hours, and the cost about thirty shillings. I think the tendency is towards distribution by special mains.

If there is no further discussion on the paper, Mr. Ware, who has presented the paper for the author, will close the discussion.

Mr. R. C. Ware :—Not having been in Europe for four years, I am not well fitted to answer the questions which have come up, but I believe that Dr. Bell and Mr. Litle have answered most of them.

The spacing of the lamps, about which Mr. Forstall asked, as I understand it, is about 100 feet on a side, the lamps being staggered on opposite sides of the street. The height, as I remember, varied from 14 or 16 to 18 feet. About the cluster lamp, I only remember some in the Place de Le Concorde in Paris, and those, as I recall, were groups of six or eight lamps arranged in a pyramidal form, and about a foot apart.

DESIGN OF THE ILLUMINATION OF THE NEW YORK CITY CARNEGIE LIBRARIES.[1]

BY L. B. MARKS.

The design of the illumination of a public library involves considerations which are quite unlike those that ordinarily confront the illuminating engineer, and are in many respects more

Fig. 1.—First Floor, Carnegie Library.

difficult to meet than in almost any other class of buildings. The design must secure:

(1) Sufficient illumination on the reading tables and book shelves to meet the demands of a wide class of readers of various ages and conditions of eyesight, taking into account the fine print in some of the books and the difficulty of reading titles of books in position on the shelves. Some of the books are worn

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

by frequent handling, and the titles become more or less obscured.

(2) Low intrinsic brightness of light sources and freedom from glare, and so far as possible removal of lights from the ordinary field of vision.

(3) Sufficient illumination for the library staff to oversee the entire floor.

(4) Sufficient illumination to provide a moderate reading light in all parts of the room, to admit of the relocation or addition of furniture, such as portable magazine filing racks, etc.

Fig. 2.—Second Floor, Carnegie Library.

(5) Moderate cost of installation.

(6) Economy of operation. This must take into account not only the system of illumination and type of lamps used but also the switching arrangements.

(7) Simplicity in construction and convenience in operation. This must take into account the character of help in local charge of the equipment.

(8) Aesthetic design of fixtures, and attractive appearance of the reading rooms at night.

The present paper is a preliminary one and deals with the design of illumination of the new Carnegie Branches of the New York Public Library, and in particular with the St. Gabriel's Park Branch which is representative of seven other Carnegie Library buildings which are now under construction in New York City. The St. Gabriel's Park Branch of which Messrs.

Fig. 3.—Third Floor, Carnegie Library.

McKim, Mead & White were the architects, was opened to the public a few months ago. Drawings of floor plans showing location of lamp outlets, switches, etc., as well as dimensions of rooms in the building and position of furniture are given herewith, (Figs. 5-10). The light units are designated at each outlet and shown on the plans on the basis of 50 watt units. Fixture drawings (Figs. 12-25) by Mr. W. S. Kellogg, Supervising Architect of the Works, schedule of lamps, and photographs of the four main floors of the building are also given.

The lighting service is taken from the direct current three

wire mains of the New York Edison Company and enters the building in the basement from which it is distributed throughout the building through panel boxes located on each floor. These panel boxes contain the switches which control the individual circuits.

DESCRIPTION OF ROOMS.

BASEMENT:

The basement contains the packing and receiving room, boiler

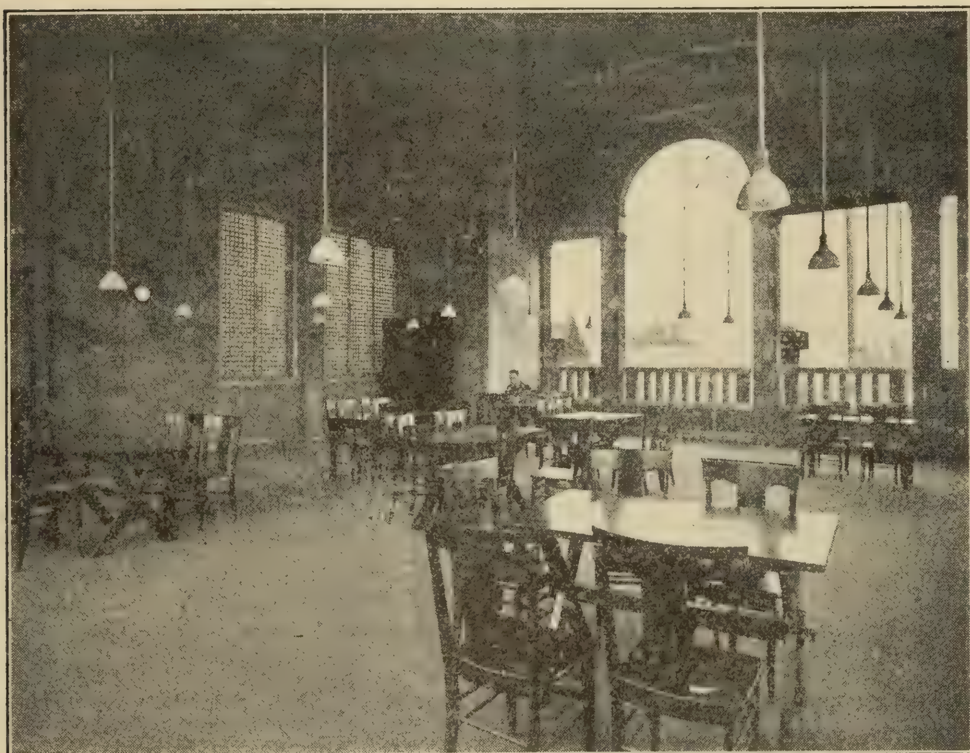


Fig. 4.—Roof Reading Room, Carnegie Library.

room, coal vault, store room and lavatory. The walls and ceilings of this room are white in color.

FIRST FLOOR:

The main entrance to the building is on the first floor. With the exception of the vestibule and small office which are separated from the rest of the room by glazed partitions, this floor constitutes one large room. In the front of the room is the circulating department, in the middle the application and delivery desk, and in the rear portion the free standing book stacks and the reference room. These departments are separated from each

other by low rails or low bookshelves. Along the walls of the room are bookcases about 7 feet high. The walls are cream color and the ceiling white. The public has access to all of the bookshelves. In the entrance hall are located two exhibition

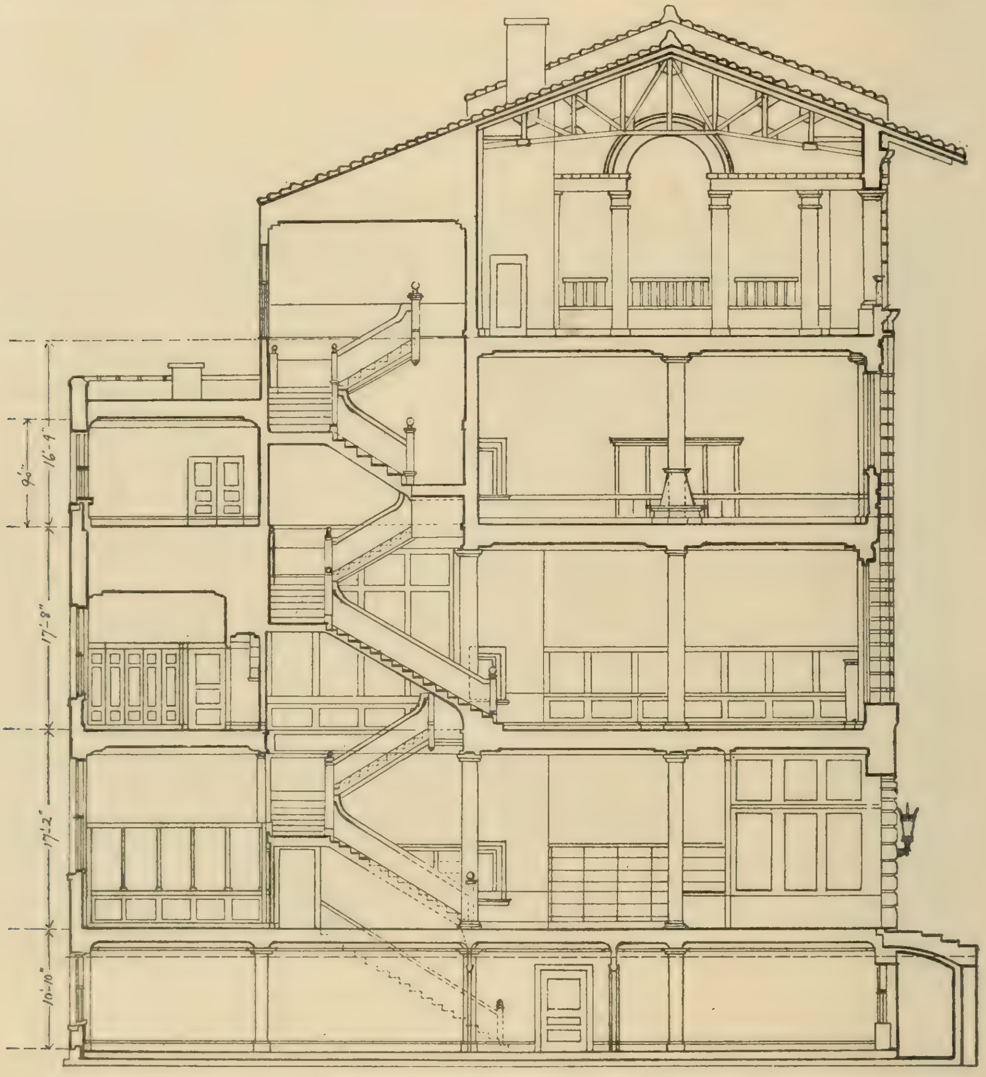


Fig. 5.—Longitudinal Section of Library Building.

racks of the swing frame type. The switches for controlling the lights are in charge of the librarian.

SECOND FLOOR:

This floor contains the children's reference room and circulating department, and the librarian's room. The conditions are very much the same as on the floor below.

THIRD FLOOR:

The main reading room and the janitor's apartments are on

the third floor. In addition to the reading tables in the main

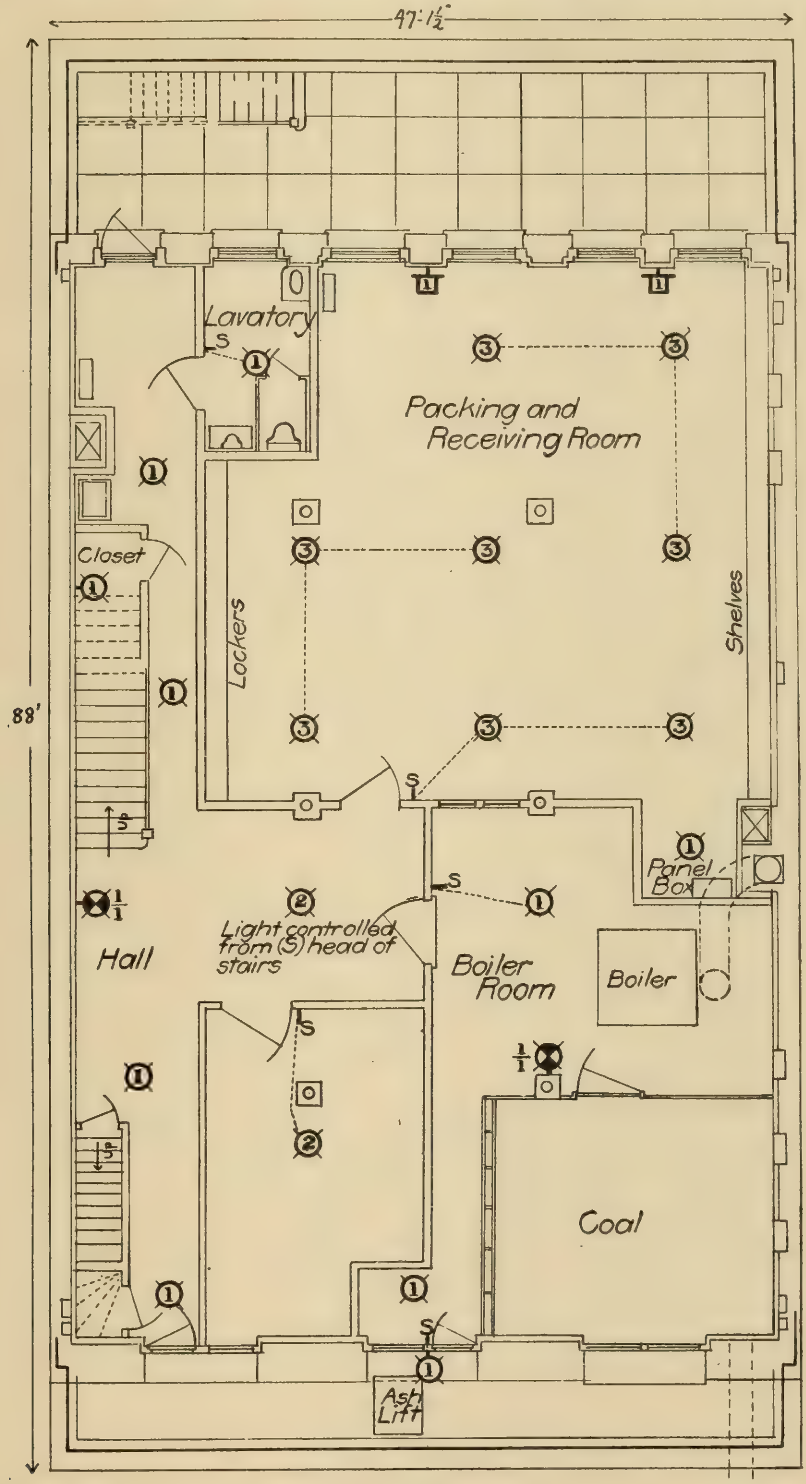


Fig. 6.—Basement Plan.

room there are two circular seats for readers around the col-

umns; also two exhibition cases for the display of photographs, prints, etc. The room contains portable magazine and newspaper racks but has no bookshelves.

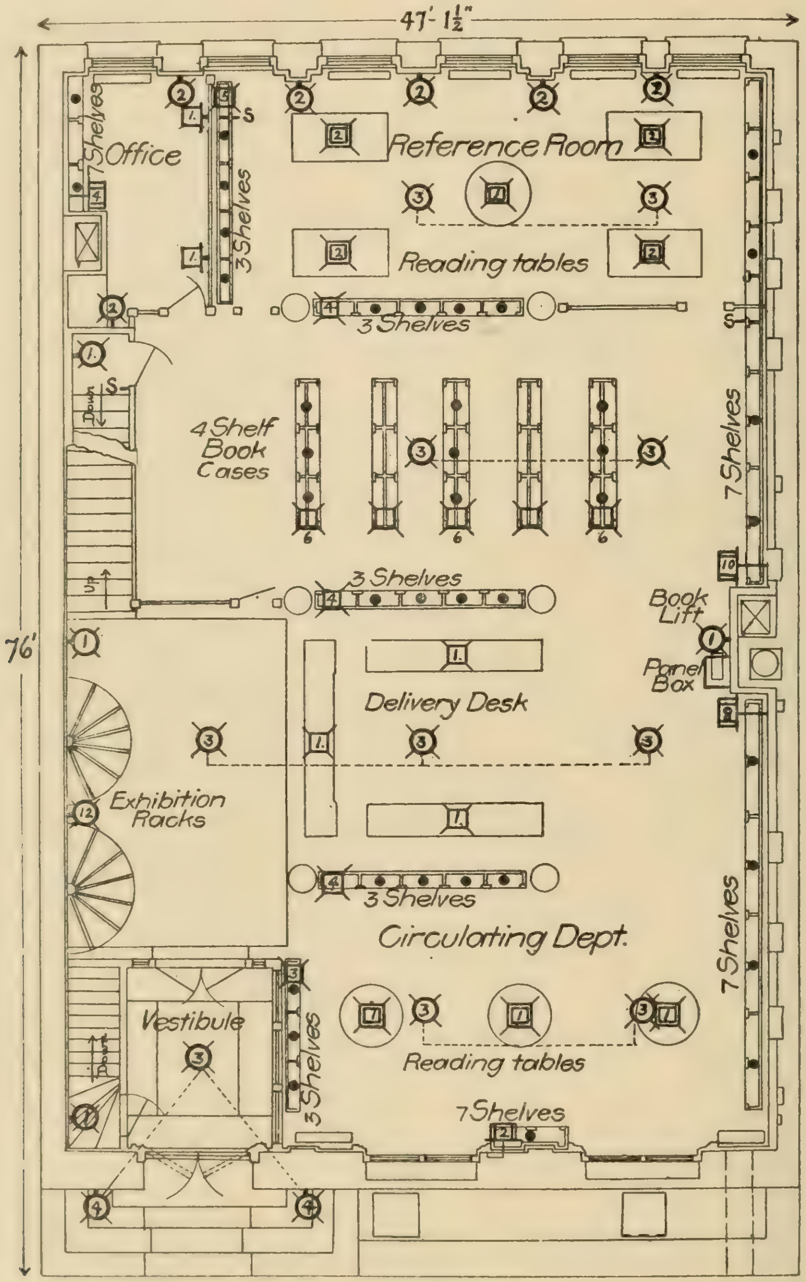


Fig. 7.—First Floor Plan.

ROOF:

The roof is used as an open air reading room. The floor of this room is of dark colored tile, the walls red brick, and the

ceiling formed by a roof of dark colored tile supported on trusses.

CARNEGIE LIBRARY. ST. GABRIEL'S PARK BRANCH.

Fixture and Lamp Schedule.

Basement. Height, 9′–6″.

No. of pieces	Drawing No.	No. of lamps Gas	No. of lamps Elec.	Description of lamps (Special / Regular)	Height of globe holder	Name of room Location of lamp	Remarks
1	4 A		1	16-c.p. Edison		Front area	Bracket lamp weather proof socket
2	15 A		2	16-c.p. Edison Frosted	7′–0″	Boiler room Coal and ash	Ceiling pendant
1	3 A	1	1	8-c.p. Ed.			Comb. bracket
1	1 A		1	8-c.p. Ed.			Elect. bracket
4	15 G		4	16-c.p. Ed.	7′–6″	Halls	1-lamp pendant 6″ ball Crystal rough outside
1	15 H		1	32-c.p. Ed.	7′–8″	Halls	1-lamp pendant 8″ x 4″ C. R. O. ball
1	3 F	1	1	8-c.p. Ed.		Hall at foot of stairs	1 comb. bracket chain pull
1	1 F		1	8-c.p. Ed.		Closet under stairs	Elect. bracket lamp up, Ch.p.
1			1	16-c.p. Ed. Frosted	At ceil.	Toilet	Elect. ceiling outlet prismatic
1	17 B		1	16-c.p. Ed. frosted tip	7′–6″	Work rm. by B.L.	1-lamp pendant Ch. p.
8	6 B		24	16-c.p. Ed. Frosted tip	7′–6″	Work rm. ceil.	Ceil. pendant Length of arm = 1′–3″ each 3 elec.
1	15 A		1	32-c.p. Ed.	9′–0″	Store room	1-lamp pend. ant
2			2	16-c.p. Ed. Frosted		2 flexible portables with fluted glass shades	

First Story. Height, 15′-3″.

No of pieces	Drawing No.	No. of lamps Gas	No. of lamps Elec.	Description of lamps Special	Description of lamps Regular	Height of globe holder	Name of room Location of lamp	Remarks
1	18		1		187-watt Gem	12′-6″	Ent. vest.	1-lamp pend-ball 16″ C. R. O.
1	2	1					Ent. vest.	Gas wall bracket
1	3 F	1	1		8 c.p. Ed.		Top of stairs by ent. vest.	1-lamp bracket, smoke bell over, ch. p.
2	19		12		8-c.p. Ed. Frosted tip	7′-3½″	On west wall over swinging frames	
1	3 F	1	1		8-c.p. Ed.		Foot of stairs up	1 comb. bracket ch. p.
1	1 F		1		8-c.p. Ed.		Under main stairs on the landing to basement	1 elect. bracket, lamp up. Ch. p.
2	5 B		4		16-c.p. Ed. Frost. tip		Office	2-lamp brackets ch. p.
4	5 B		8		16-c.p. Ed. Frost. tip		Reference Rm.	2-lamp brackets Proj. 15″ from wall to cen. of lamp; lamps down. Ch. p.
1	1 B		1		16.c.p. Ed. Frost. tip		Book lift	1-lamp bracket lamp down Ch. p.
9	18		9		16-c.p. Ed.	12′-6″	Main room	Ceiling pendant 16-in CRO ball
2	10		4		16-c.p. Ed. Frosted		Shelves in office	2 mirror reflectors
10	10		20		16.c.p. Ed.		7 shelf cases in main room	Mirror reflectors
20	9		20		8-c.p. Ed		3 shelf cases in main room	Revolving fixtures
9	R 7 D		18		20-c.p. 50-watt Gem	7′-2″	4 shelf free standing cases	Exact spread of arms given later (about 5′-0″)
3	8 E		3		16-c.p. Ed Frosted		Delivery desks	Adjustable revolving standard

First Story.—(Continued).

No. of pieces	Drawing No.	No. of lamps: Gas	No. of lamps: Elec.	Description of lamps: Special	Description of lamps: Regular	Height of globe holder	Name of room Location of lamp	Remarks
3	14		3	40-watt Tantalum Frosted			Circulation room	On round tables
1	14		1	40-watt Tantalum Frosted			Reference room	On round tables
4	L 7 C		8		16-c.p. Ed. Frosted		Reference room	Rectangular tables Spread = 3′–0″ for 6′–0″ table and 2′–6″ for 5′–0″ table
2			2	16-c.p. Ed. Frosted			2 flexible portables with fluted glass shades	

Second Story. Height, 15′–6″.

No. of pieces	Drawing No.	No. of lamps: Gas	No. of lamps: Elec.	Description of lamps: Special	Description of lamps: Regular	Height of globe holder	Name of room Location of lamp	Remarks
1	3 F	1	1		8-c.p. Ed.		Stair landing 1st to 2nd	Combination bracket Ch. p.
1	3 F	1	1		8-c.p. Ed.		Foot of stairs up	Combination bracket Ch. p.
1	1 B		1		16-c.p. Ed. Frosted tip		Book lift	Bracket, Lamp down Ch. p.
2	5 B		4		16-c.p. Ed. Frosted tip		Rear of circulation room	2-lamp bracket, Lamps down, Lamps 15″ from wall Ch. p.
4	1 B		4		16-c.p. Ed. Frosted tip		Column over seat	1-lamp bracket Lamps down
1	1		1		8-c.p. Ed.		Slop sink	Lamp down No shade Ch. p.
1			1		16-c.p. Ed. Frosted tip		Toilet	Elec. ceiling outlet Prismatic

Second Story.—(Continued).

No. of pieces	Drawing No.	No. of lamps Gas	Elec.	Description of lamps Special	Regular	Height of globe holder	Name of room Location of lamp	Remarks
1	6 B		6		16-c.p. Ed. Frosted tip	7′–6″ (ceil. 12′–0″)	Librarians room	6-lamp ceil. pendant Spread=2′-6″
2	1 B		2		16-c.p. Ed. Frosted tip		Librarians room	Brackets, Lamp down, Ch. p.
16	9		16		8-c.p. Ed.		3 shelf cases	Revolving bracket
11	11		22		16-c.p. Ed.		5 shelf cases	Mirror reflector
4	11		8		16-c.p. Ed.		Bulletin board	Mirror reflector
2	14		2	40-watt Tantalum Frosted			Circulating room	Round tables
4	L 7 C		8		16-c.p. Ed. Frosted tip		Reference room	Rectangular tables,
3	8 E		3		16-c.p. Ed. Frosted tip		Delivery desk	Revolving Adj. Standard
9	18		9		187-watt Gem	12′–6″	Ceiling main room	16″ C. R. O. Pend. balls

Third Story. Height, 15′–0″.

Janitors Apartments. Height, 9′–0″.

No. of pieces	Drawing No.	No. of lamps Gas	Elec.	Description of lamps Special	Regular	Height of globe holder	Name of room Location of lamp	Remarks
6	18		6		187-watt Gem	12′–6″	Ceil. main room (reading)	16″ C. R. O. Pend. balls
3	3 F	3	3		8-c.p. Ed.		Comb. brackets on stairs, Ch. p.	
2	3 F	2	2		8-c.p. Ed.		Janitors Hall	Comb. brackets, Smoke bells, Ch. p.
4		4	4		16-c.p. Ed.		Janitors bed rooms	Comb. brackets, Smoke bells, Ch. p.

Third Story.—(Continued).

No. of pieces	Drawing No.	No. of lamps Gas	Elec.	Description of lamps Special	Regular	Height of globe holder	Name of room Location of lamp	Remarks
1	3 F	1	1		16-c.p. Ed.		Janitors bath	Comb. brackets, Smoke bells, Ch. p.
1	6 G	4	4		16-c.p. Ed.	6′–6″	Janitor's living room	Comb. ceiling pendant Spread=2′-0″
1			4		16-c.p. Ed. Frosted	8′–0″	Kitchen ceiling	Cluster porcelain reflector
1	3 F	1	1		16-c.p. Ed. Frosted		Kitchen wall	Comb. bracket over tubs Ch. p.
1	1 A		1		8-c.p. Ed.		Janitor's stairs to roof	Lamp up
10	13		10	Straight filament lamps			Reading room Ex. cases	"Linolite"
2	1 B		2		16-c.p. Ed. Frosted		Reading room over folio cases	Lamp down 15″ from wall Ch. p.
8	1 B		8		16-c.p. Ed. Frosted		Reading room, Cols. over seats	Lamp down 15″ from wall Ch. p.
1	1 B		1		16-c.p. Ed. Frosted		Book lift	Lamp down Ch. p.
9	L 7 C		18		16-c.p. Ed. Frosted		Reading room tables	
2			2		16-c.p. Ed. Frosted		2 flexible portables with fluted glass shades	

Roof. Height, 20′–0″ to truss.

No. of pieces	Drawing No.	No. of lamps Gas	Elec.	Description of lamps Special	Regular	Height of globe holder	Name of room Location of lamp	Remarks
3			3		32-c.p. Ed. Frosted	8′–0″	Hall	1-lamp, Elec. pendants Prismatic enameled
2	2	2					N. wall	Gas brackets
2	1 A		2		16-c.p. Ed.		Book lift and motor room	Ch. p.
23	16		16		125-watt Gem with frosted tip	7′–0″	From stair platform to shade holder	Enameled reflectors

ILLUMINATION TESTS.

Tests of illumination were made under my direction by the Electrical Testing Laboratories, on the first floor and in the roof reading room.

The first floor dimensions are approximately 67 feet by 44

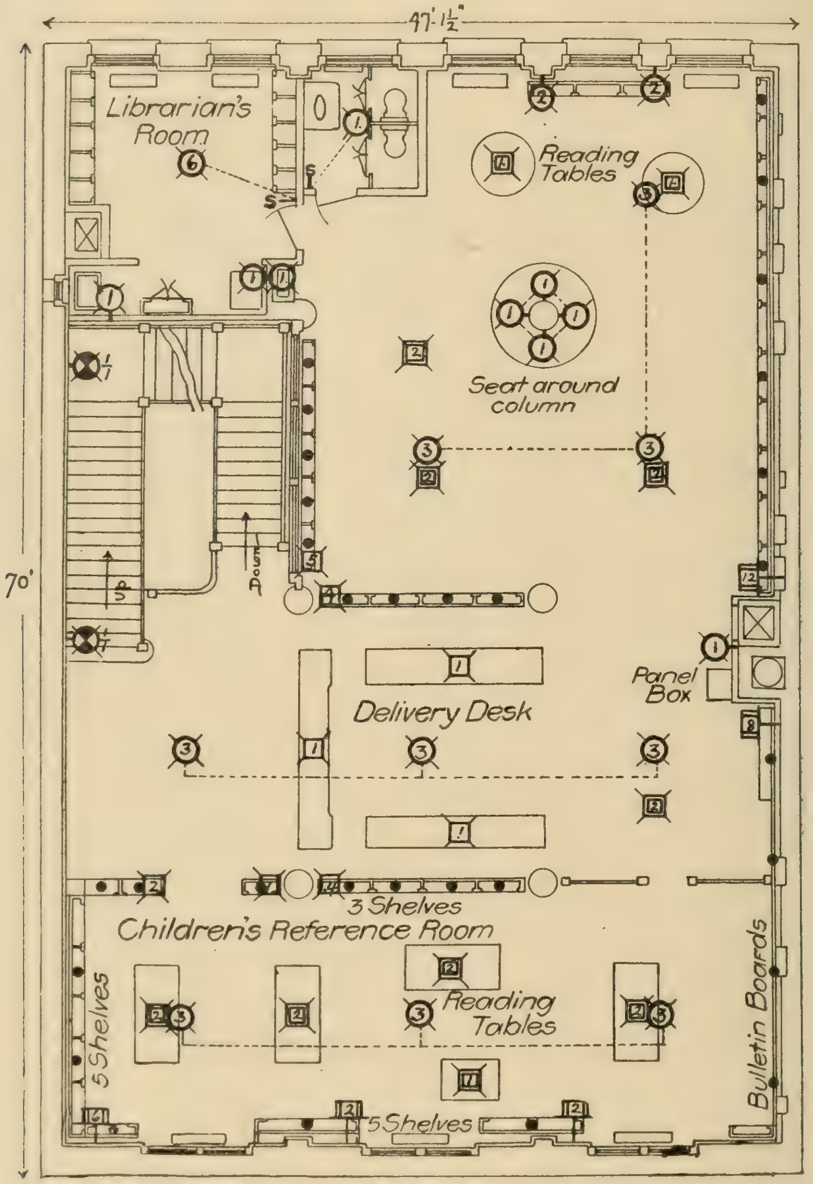


Fig. 8.—Second Floor Plan.

feet, and the height of the ceiling is 15 feet 3 inches in the clear. General illumination is provided by 10, 187 watt ceiling pendant lamps, each equipped with a prismatic reflector, both lamp

and reflector being enclosed in a 16 inch crystal globe roughed on the outside. The height of the lamps above the floor is 12 feet 6 inches. The localized illumination is provided on the reading tables, stacks, bookshelves, etc., and may be used in whole or in

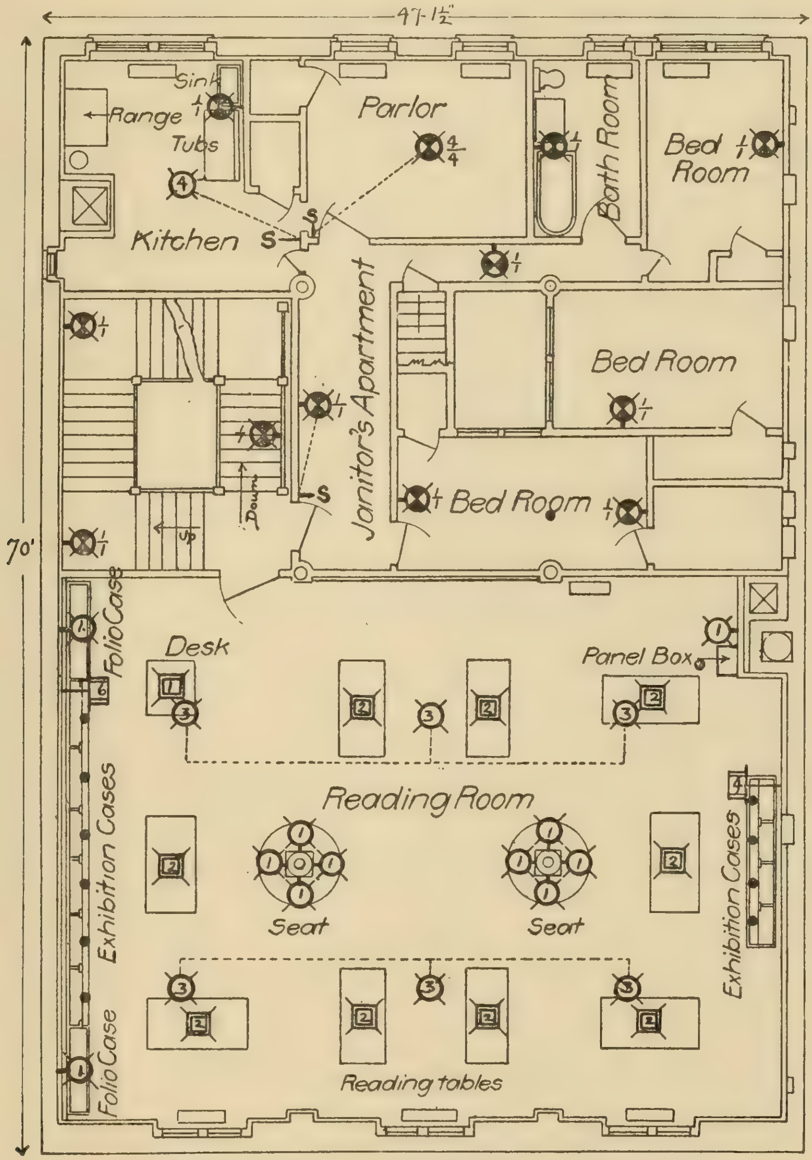


Fig. 9.—Third Floor Plan.

part depending upon the requirements, permitting lamps in the reading tables or on bookshelves, to be extinguished when not required.

The free standing bookcases located near the rear of the room are 52 inches high and 9 feet 6 inches long, divided into

four shelves 9 inches apart. These are illuminated by 50 watt Gem lamps, backed by prismatic reflectors which are covered by opal shades, green on the outside, located 6 feet 6 inches

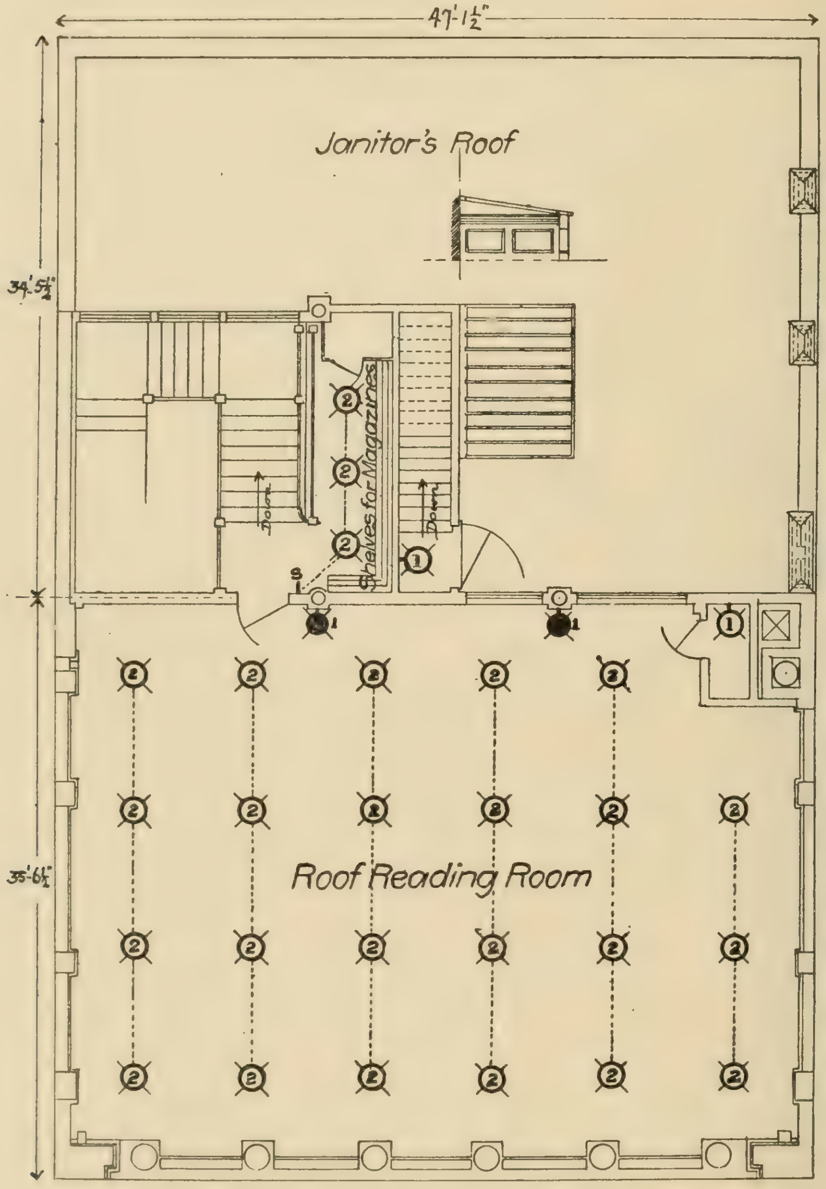


Fig. 10.—Roof Reading Room Plan.

above the floor, and immediately over the center of the aisles between stacks as illustrated on the diagram, (Fig. 28).

The seven shelf bookcases upon which tests were made are illuminated by special two-socket mirror trough wall reflectors

holding the lamps in a horizontal position, and equipped with

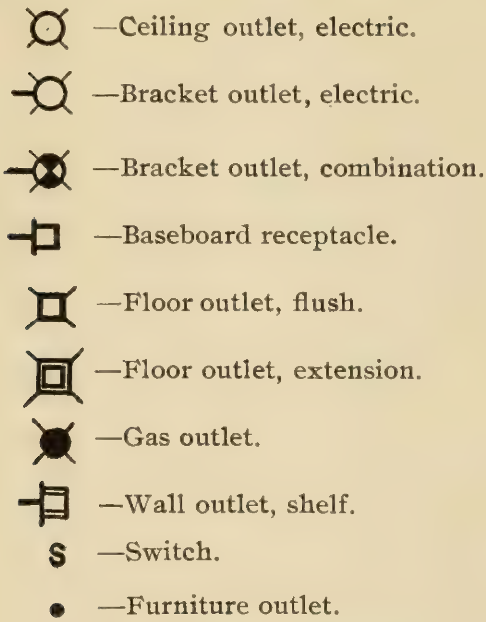


Fig. 11.—Key to Wiring Symbols.

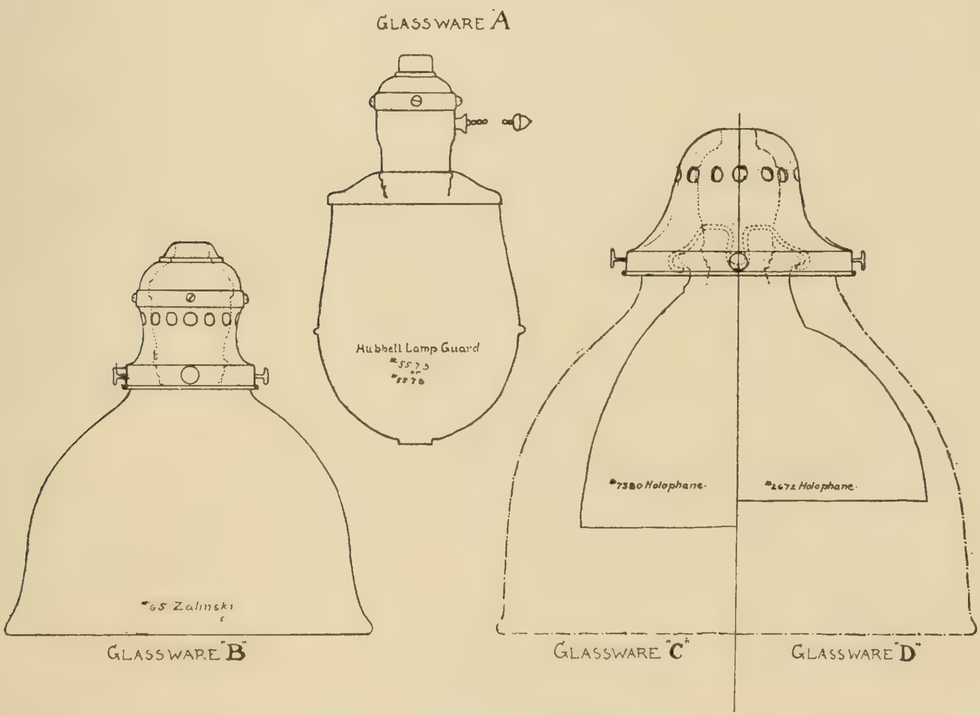


Fig. 12.—Glasswares A, B, C and D.

50 watt Gem lamps. The location of these reflectors is illustrated in the diagram, (Fig. 27).

Tests were made upon the low bookcases along the aisles.

These cases are provided with local illumination from 8-cp. carbon filament incandescent lamps on swing brackets which, when

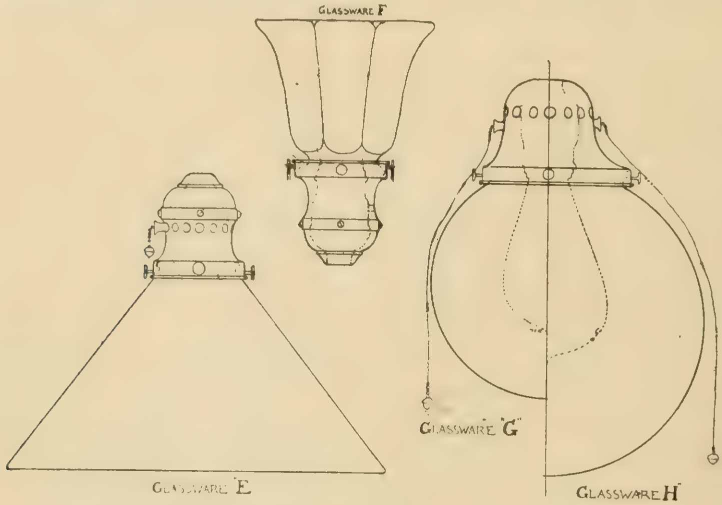


Fig. 13.—Glasswares E, F, G and H.

in use, extend 9 inches beyond the edge of the case but when out of use, are swung over the top of the rack in order to leave

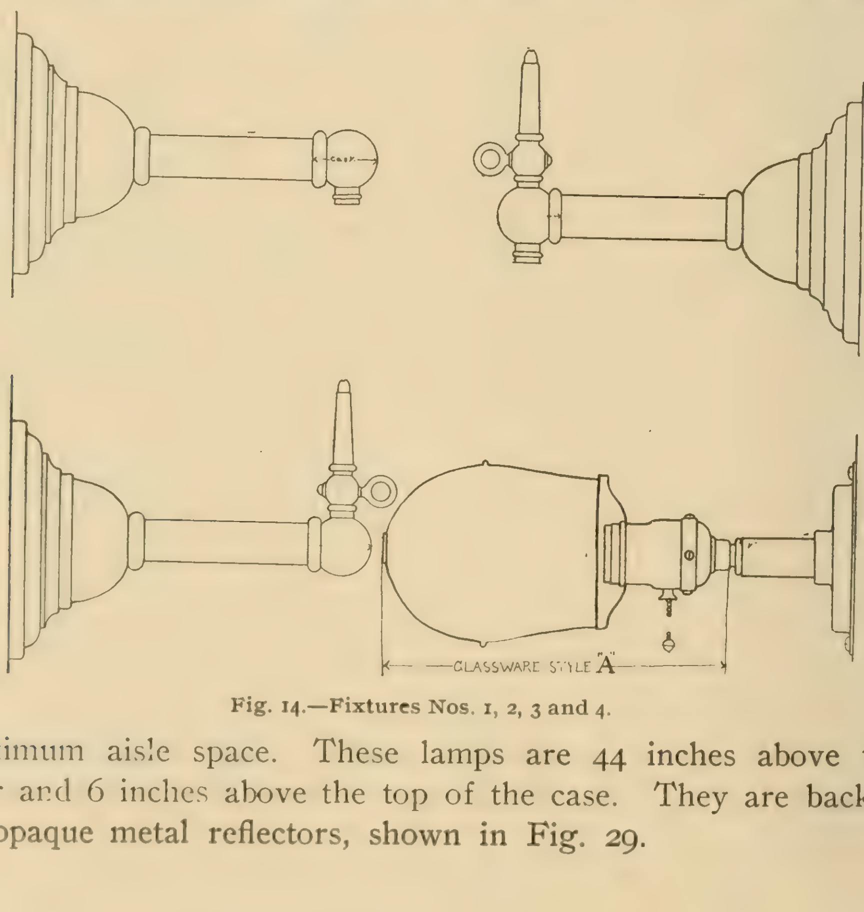


Fig. 14.—Fixtures Nos. 1, 2, 3 and 4.

maximum aisle space. These lamps are 44 inches above the floor and 6 inches above the top of the case. They are backed by opaque metal reflectors, shown in Fig. 29.

The round reading tables shown on the drawings are provided

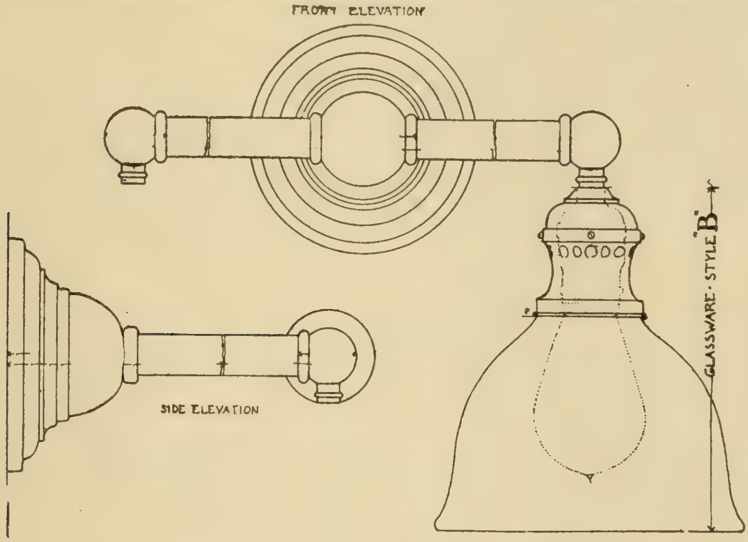


Fig. 15.—Fixture No. 5.

with local illumination from 40 watt frosted tantalum lamps in single lamp fixtures having 14 inch opal dome shades, green on

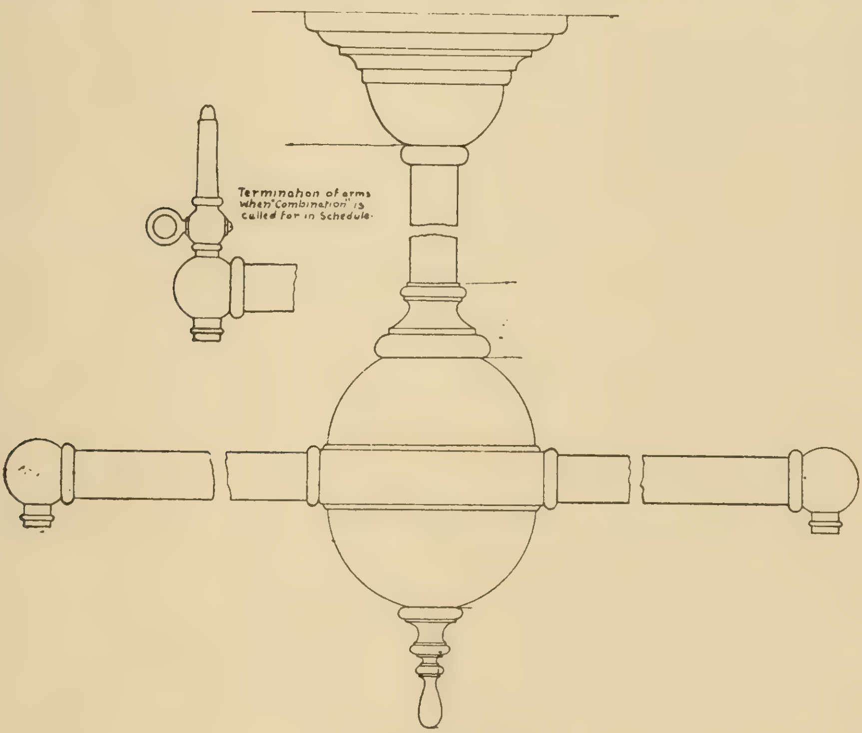


Fig. 16.—Fixture No. 6.

the outside. Immediately over the lamps and inside the dome shades are placed prismatic reflectors. These fixtures are placed

at the centers of the tables, with the tantalum lamps 20 inches above the table top, as shown in Fig. 30.

The rectangular tables (Fig. 29) in the rear of the room, are illuminated by frosted 16 c.p. Edison lamps, equipped with reflectors of the same type as those used on the round reading tables. The test was made on one of the tables which was equipped by mistake with 40 watt tantalum lamps instead

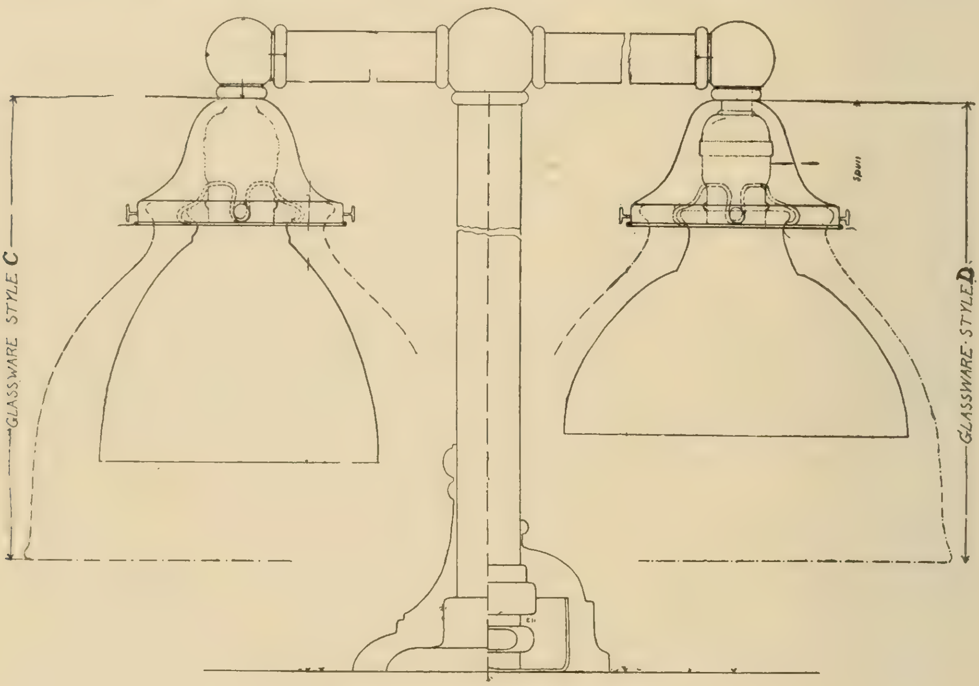


Fig. 17.—Fixtures Nos. 7L and 7R.

of 16 c.p. Edison lamps, and the error was not discovered until it was too late to complete further measurements with lower candle-power lamps in time for presentation in this paper.

Figure 31 in a plan of the reading room showing the approximate location of tables and light sources. In this case 125 watt tip-frosted Gem lamps are used in conjunction with a temporary installation of prismatic reflectors sand blasted inside. The tables are not fastened as they are in the floors below.

CONDITIONS OF TEST.

Most of the lamps in this installation were installed over two months ago and have experienced a normal amount of service since installation. As slight fluctuations in voltage were to be anticipated, and as it was desired to obtain results which would

be free from the influence of such fluctuations, it was decided to make the photometric comparisons with a standard lamp operated

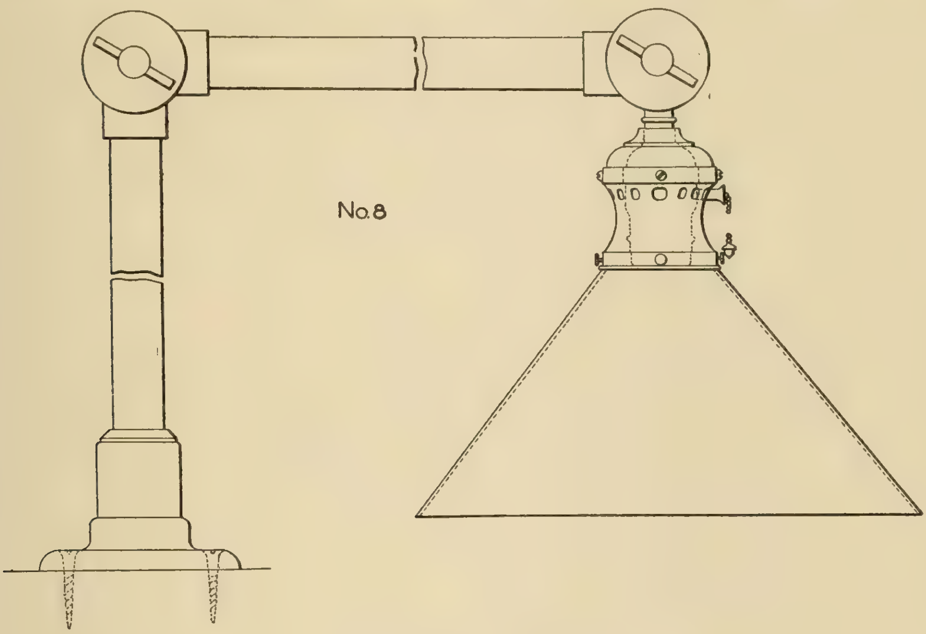


Fig. 18.—Fixture No. 8.

from the lighting system, and subject to the same fluctuations in voltage as were the lamps which were under test. Under these

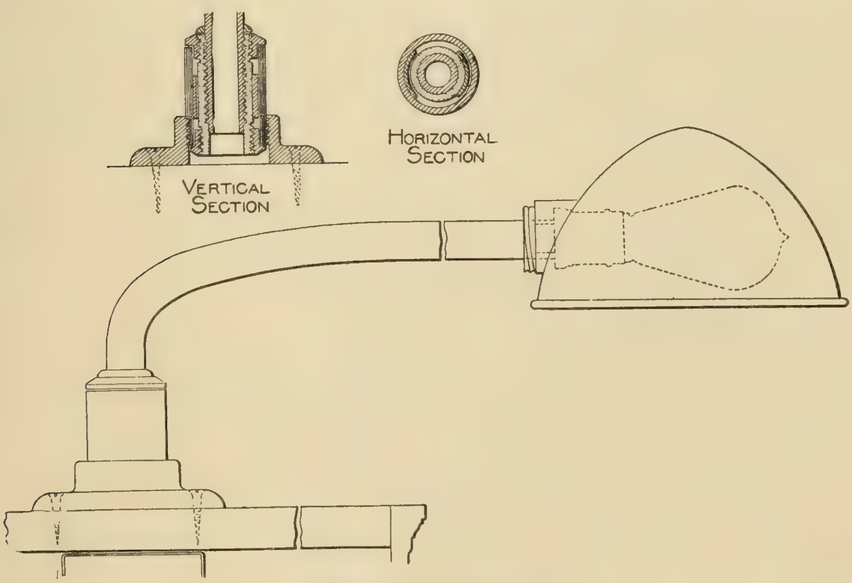


Fig. 19.—Fixture No. 9.

conditions accurate results are secured which are intercomparable.

On the first floor tests were made to show the amount of general illumination and also to show illumination produced by both the ceiling lamps provided for general illumination and the lamps provided for local illumination.

METHODS OF TEST.

The intensity of vertical illumination was measured at points

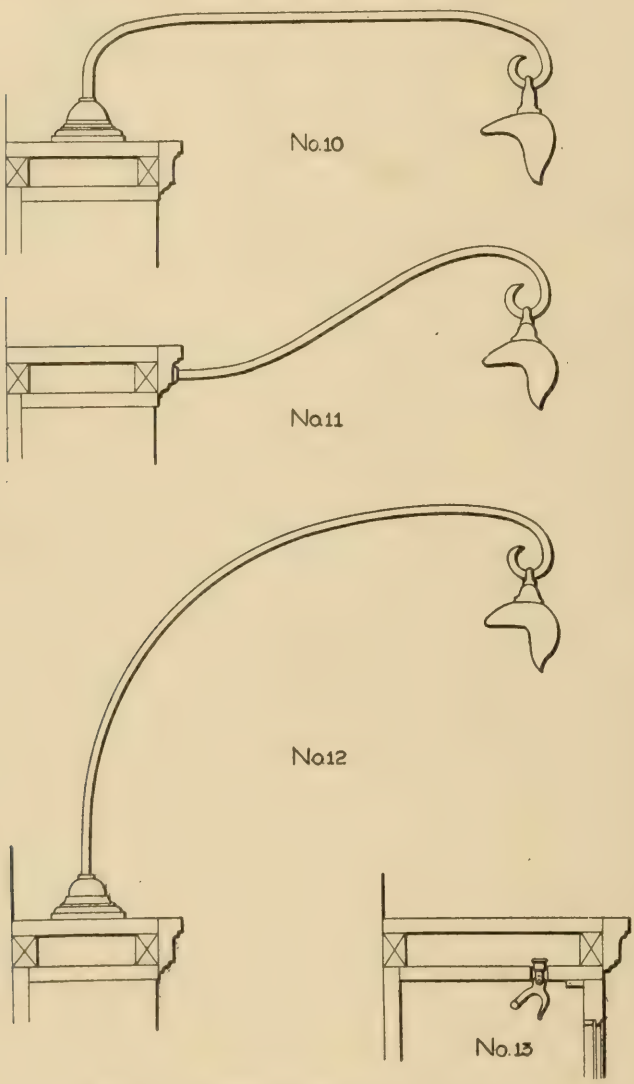


Fig. 20.—Fixtures Nos. 10, 11, 12 and 13.

on the fronts of stacks and bookshelves where it is desired to read titles on the backs of books. Tests were also made of horizontal illumination in aisles immediately in front of stacks to show illumination on books opened and held in such positions

for casual inspection. Other tests of horizontal illumination were made upon reading tables.

In conducting these tests a Sharp-Millar portable photometer was used. In tests of vertical illumination at the book stacks the photometer was placed on the shelves with the illumination test plate vertical, and in the position occupied by the title of a book. An observation under these conditions is equivalent to viewing the title from a point directly in front or to viewing

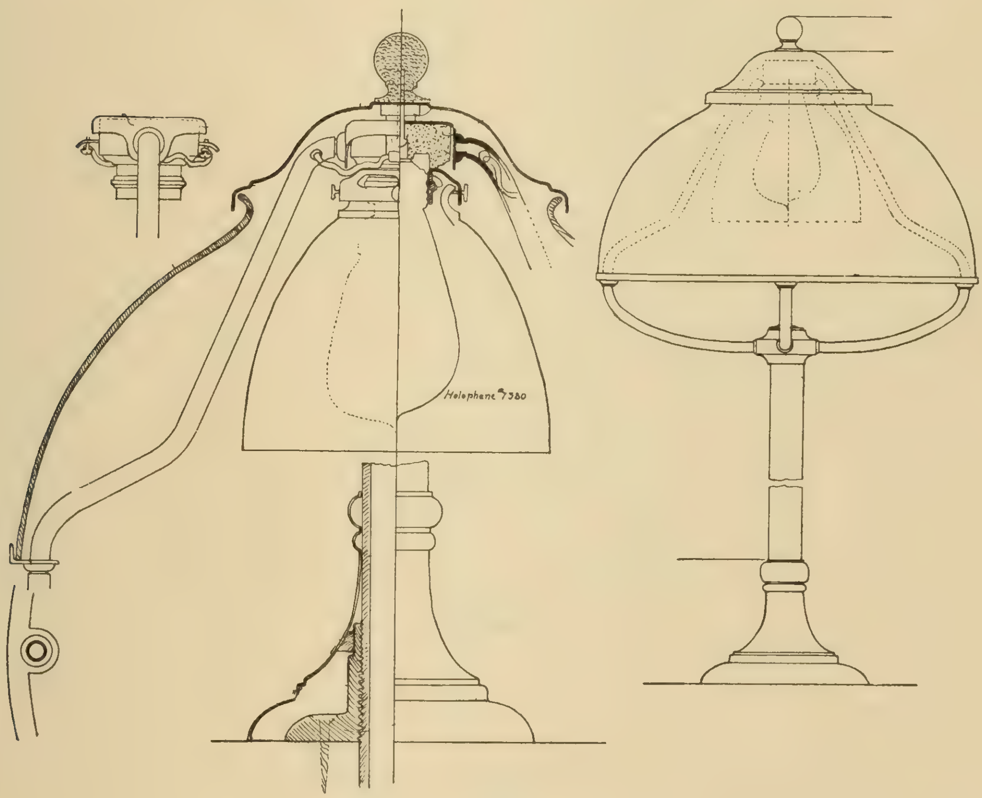


Fig. 21.—Fixture No. 14.

the test plate from a point in a line normal to its surface. Other tests of the same values were made by placing white blotting paper (used as a test plate) vertically over the backs of the books, and observing it through the photometer located at the point from which one would naturally view the titles of the books in practice. This constitutes a determination of the illumination intensity through observation of the test surface at angles varying from 45 degrees above to 40 degrees below the normal, depending upon the height of the shelf.

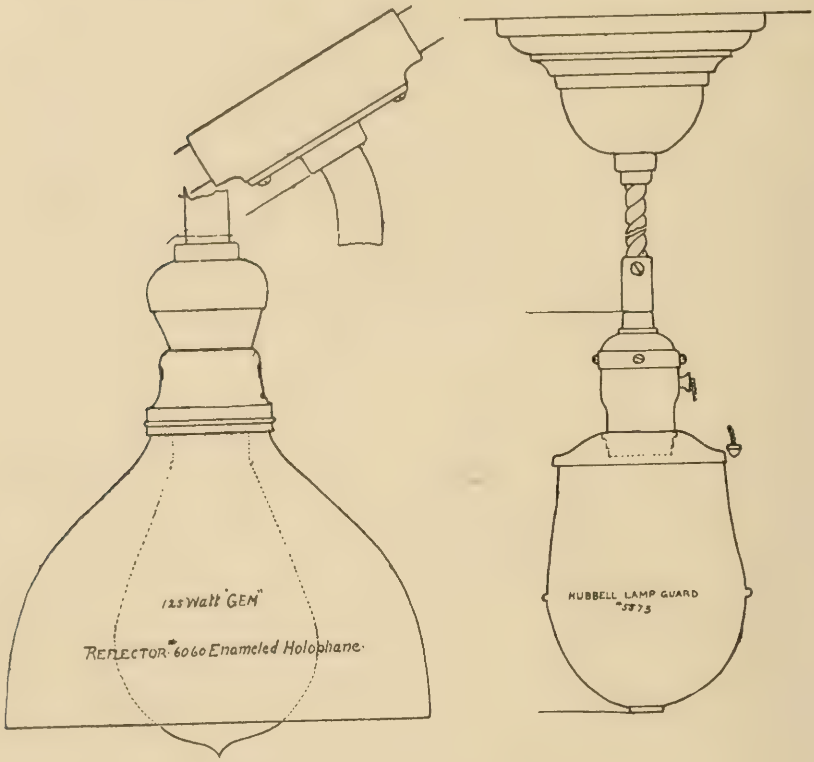


Fig. 22.—Fixtures Nos. 16 and 15.

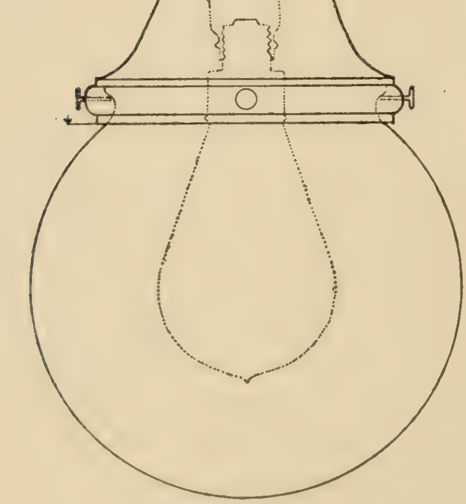


Fig. 23.—Fixture No. 17.

In all cases the illumination is stated in terms of that produced by a standard lamp placed at a known distance from the test plate which was viewed as in the test.

RESULTS OF TESTS.

Results of tests of general illumination in all the principal

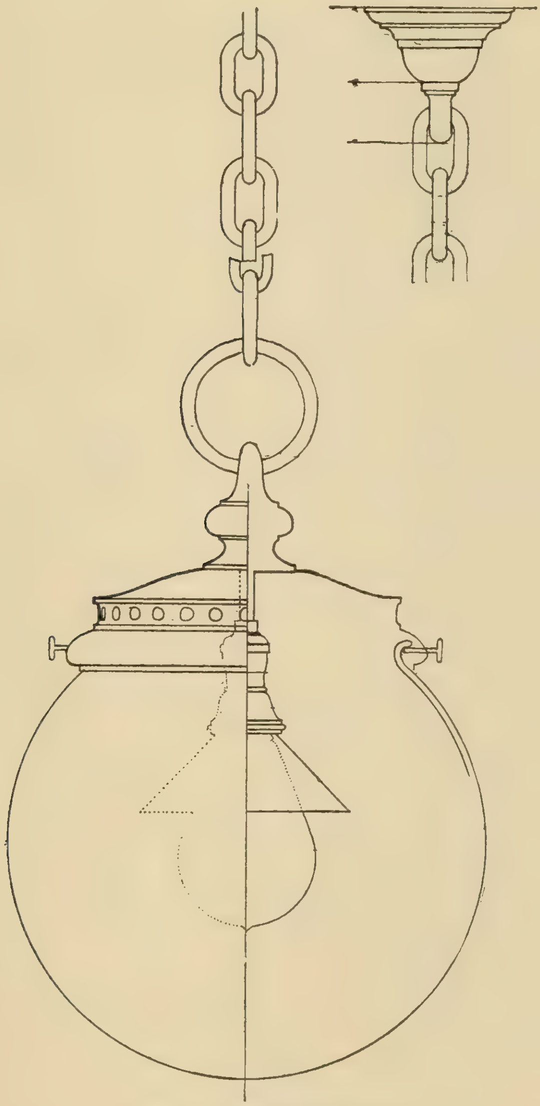


Fig. 24.—Fixture No. 18.

working positions in the room are shown in foot-candles on the accompanying chart, (Fig. 26). The measurements were made on a horizontal plane approximately 3 feet above the floor. The average of all values is 1-1/10 foot-candles. Data for this floor are as follows:

First Floor.

Area, square feet	2950
Contents, cubic feet	44950
Watts, general illumination	2316
Watts, localized illumination	4174
Total watts	6490

General Illumination.

Watts per sq. ft.	0.78
Watts per cu. ft.	0.05
Average foot candles on horizontal working plane	1.1
Foot-candles per watt per sq. ft.	1.4
Approx. spher. candle-power per sq. ft.	0.2
Approx. spher. candle-power per cu. ft.	0.012

Free Standing Book Stacks.

Results of the vertical illumination on book stacks are shown

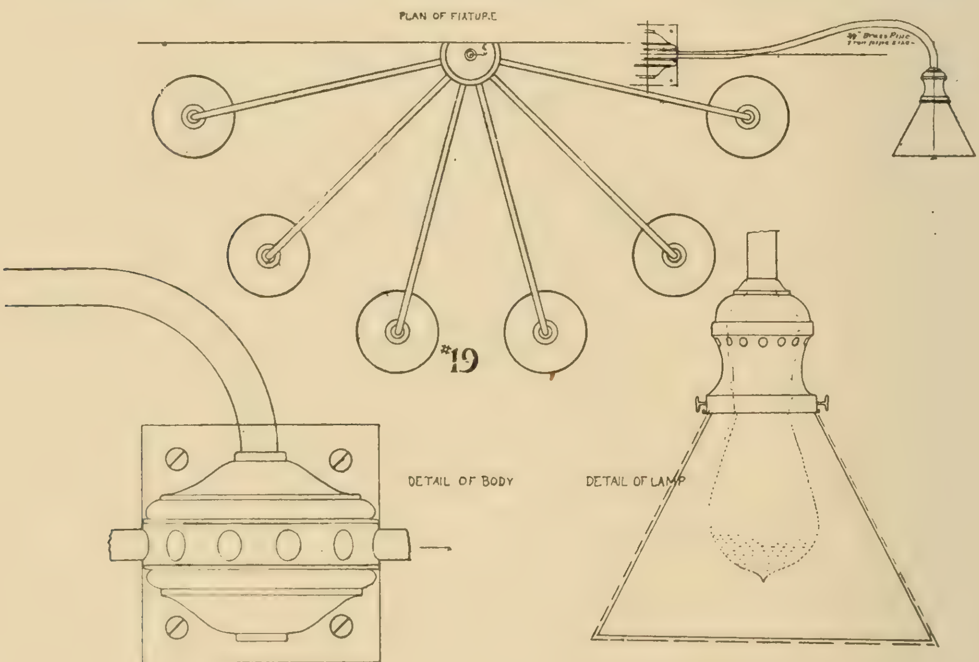


Fig. 25.—Fixture No. 19.

in foot-candles on the accompanying diagram, (Fig. 28), the approximate location of the test plate being indicated by the position of the foot-candle values on the diagram. The figures marked (*) indicate results of test obtained with the photometer on the shelves. Figures underlined indicate results obtained by viewing the test plate through the photometer from the position which

would probably be assumed by the average observer. This

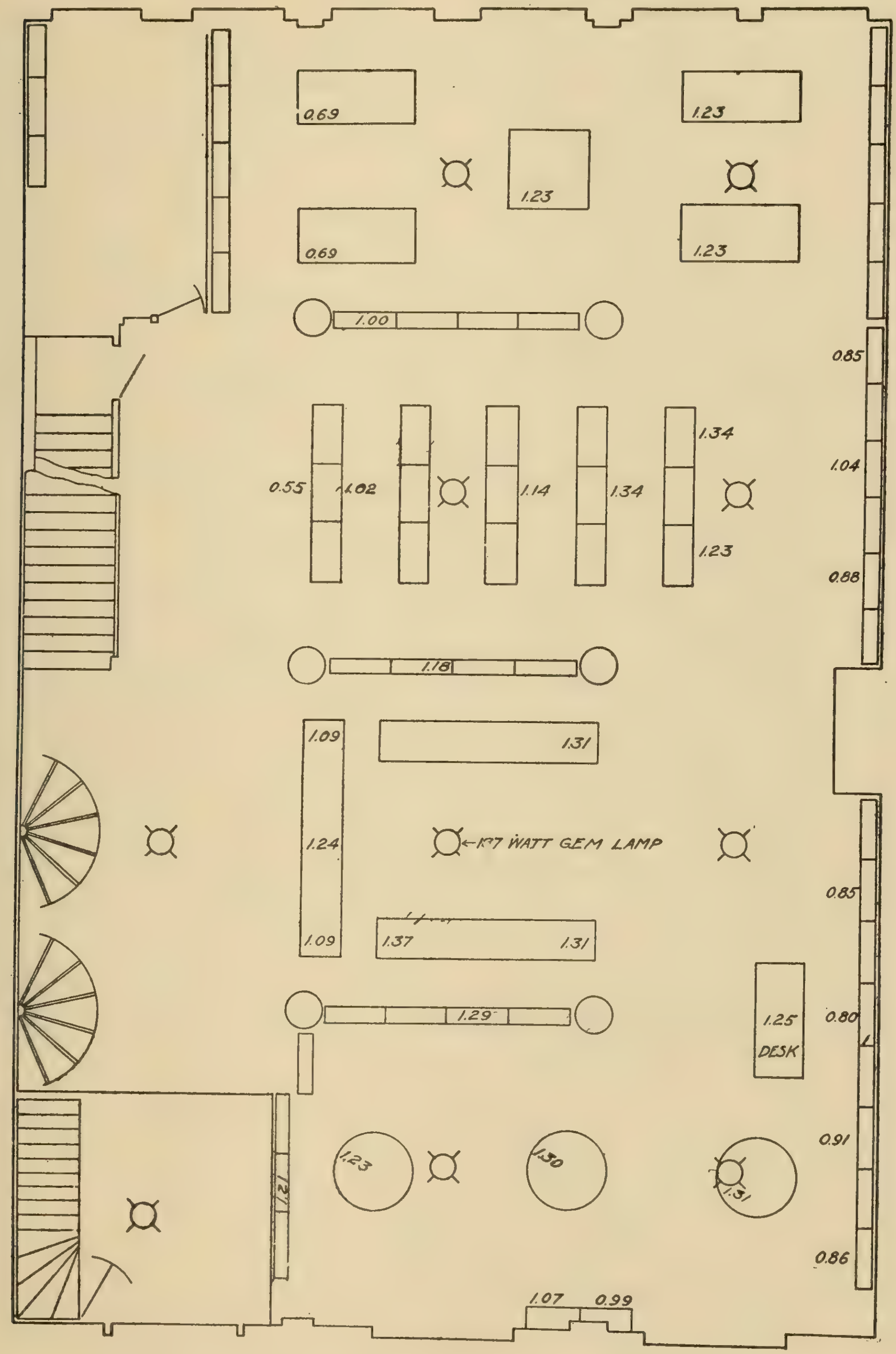
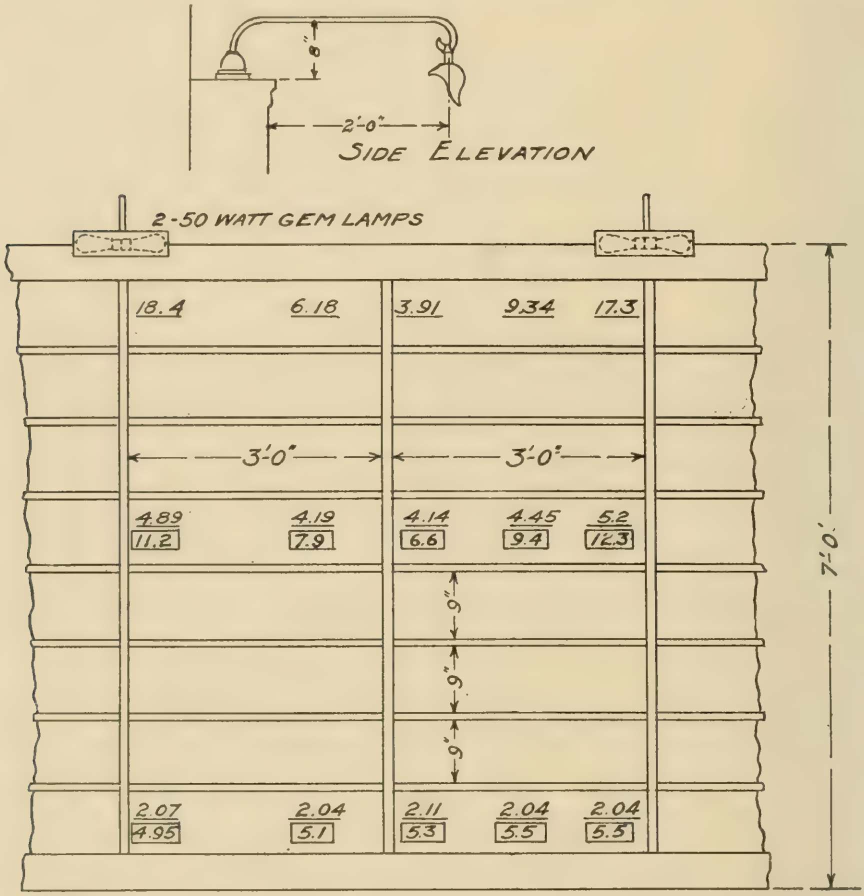


Fig. 26.—First Floor Illumination, all Local Lamps Being Extinguished.

shows that a considerable difference is found when the test plate

is viewed from different angles and when test plates of different character are used.

Tests were made to show horizontal illumination immediately in front of the stack in position where one would be likely to hold a book removed from the racks for casual examination.



FIGURES UNDERLINED SHOW FOOT CANDLES VERTICAL ILLUMINATION IN POSITIONS INDICATED
FIGURES IN ▭ SHOW FOOT CANDLES HORIZONTAL ILLUMINATION 11 INCHES AND 47 INCHES ABOVE FLOOR

Fig. 27.—Illumination on Seven-shelf Wall Book-cases.

The results of these tests are indicated on the diagram in figures inscribed in rectangles.

Seven Shelf Wall Bookcases.

The foot-candles illumination as measured on vertical white blotting paper as described in the tests of the aisle book stacks, is shown in Fig. 27, the figures underlined representing the foot-candles, and their location on the diagram indicating the location of the test plate on the bookshelves.

As in the previous test, measurements were made to determine

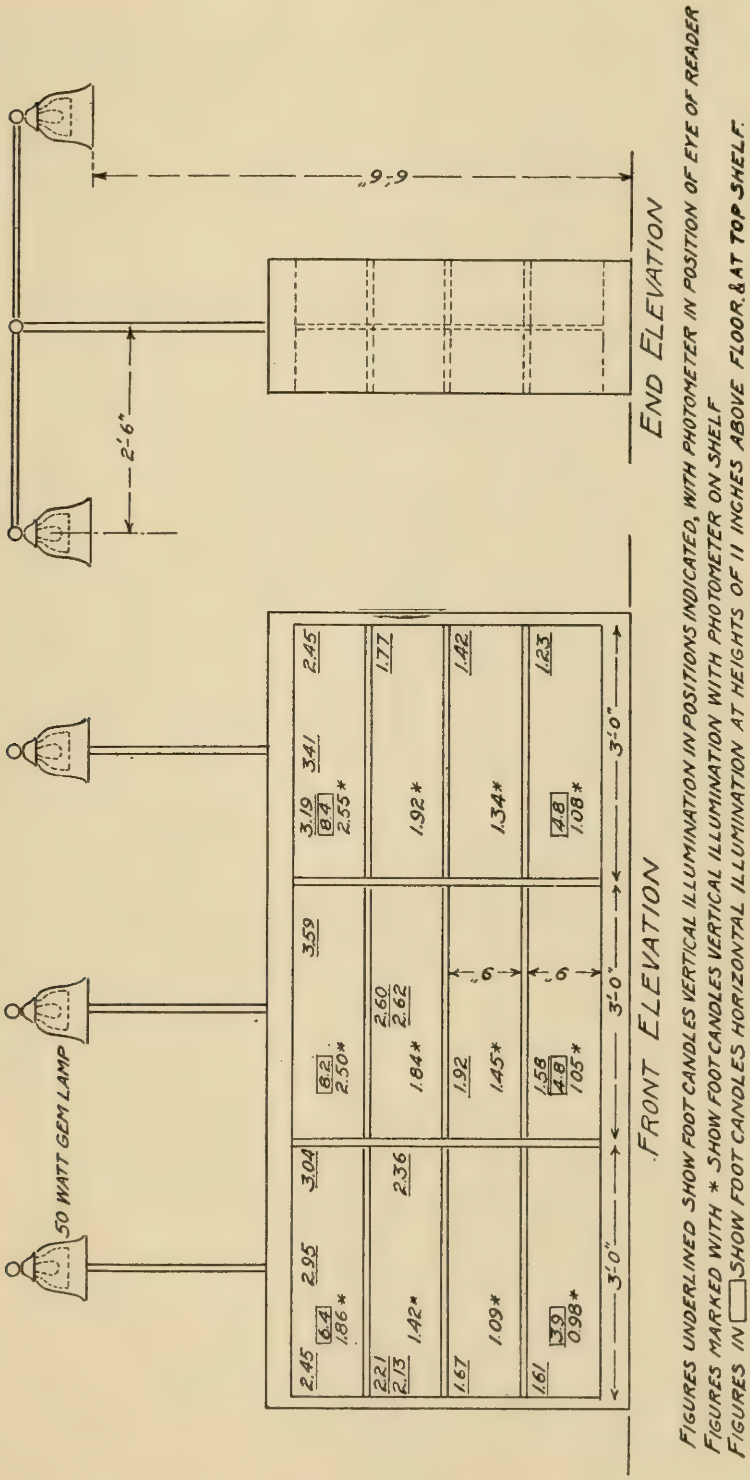


Fig. 28.—Illumination of Free Standing Book Stacks.

horizontal illumination in front of the bookshelves. These values

are indicated on the diagram in figures inscribed in rectangles.

Vertical Illumination on Low Bookshelves.

This test was conducted with a blotting paper test-plate as

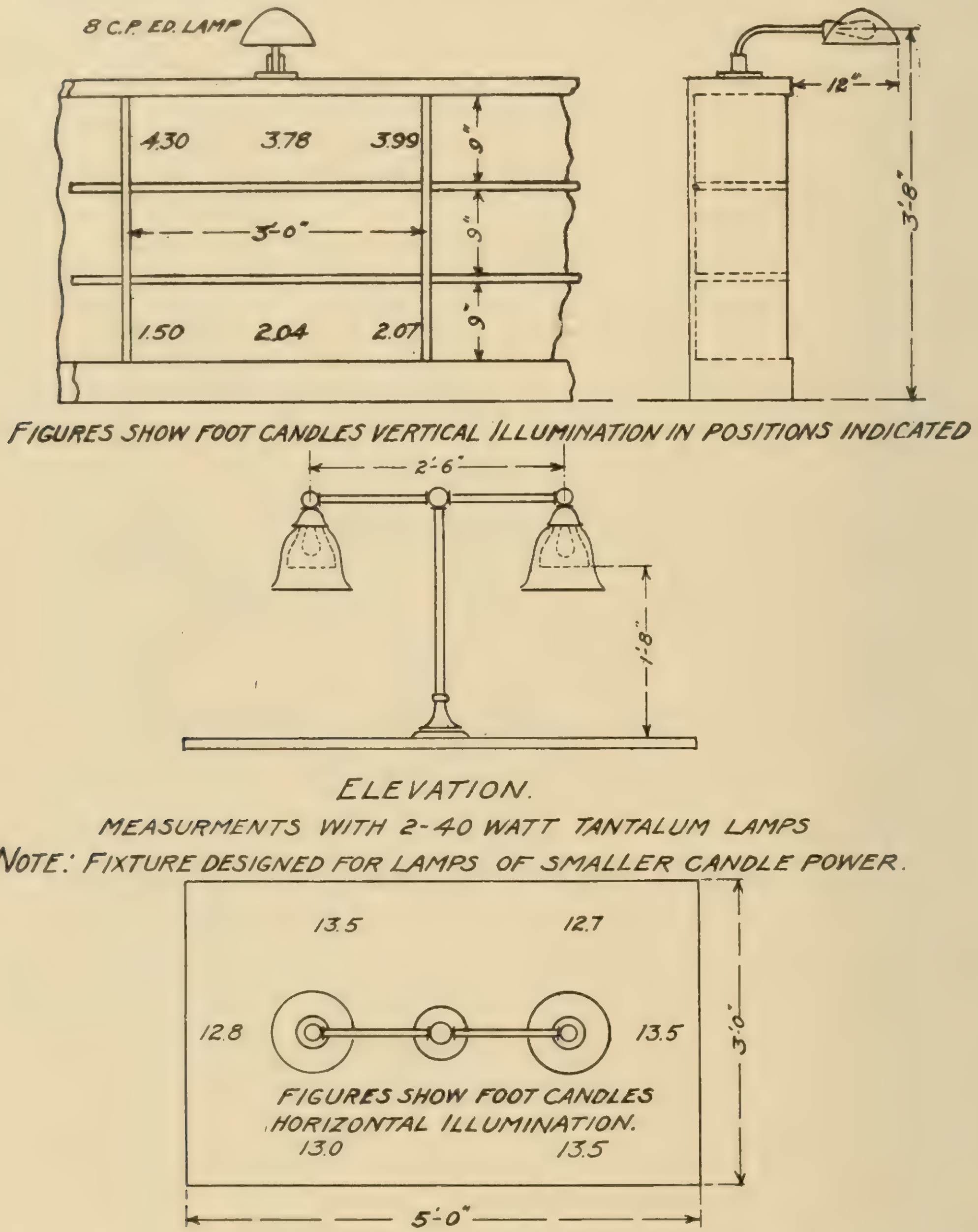


Fig. 29—Illumination of Low Book Cases and Rectangular Reading Tables.

described in the tests of the aisle book stacks. The results are indicated on the diagram, (Fig. 29), the foot-candle values being placed on the diagram in such manner as to indicate the location of the test-plate in the test.

Round Reading Tables.

Test 1. This test was made by placing the blotting paper as a test-plate upon the surface of the table and viewing it through the photometer from the angle at which the average reader would probably view a book and receive a minimum amount of regular reflection. The foot-candles illumination, angle of view and distance from the center of the table to test lamp, were as follows:

Distance from center of table to test lamp	Angle of view. with the horiz.	Horizontal illumination
6 inches	50°	7.9 ft. c.
12 inches	50°	7.5 ft. c.
18 inches	50°	7.1 ft. c.

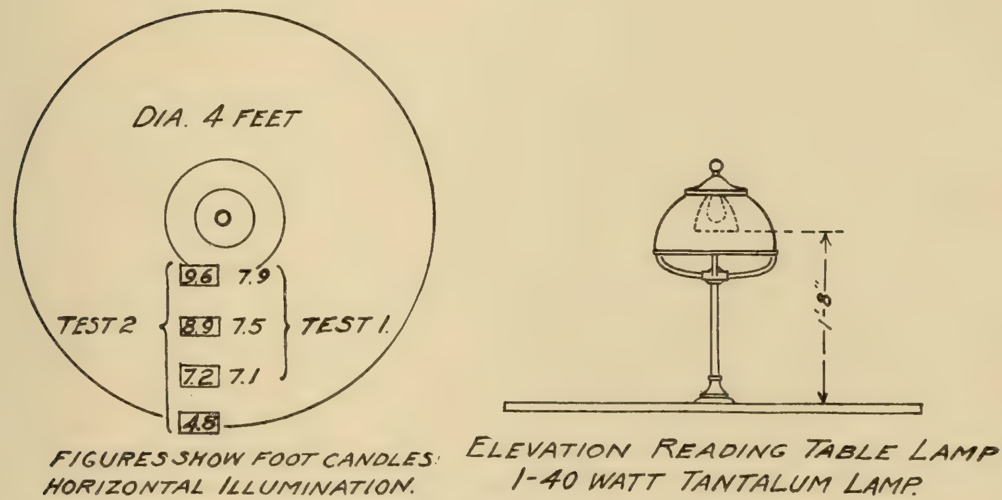


Fig. 30.—Illumination of Round Reading Tables.

The illustration (Fig. 30), shows a plan of this table and location of lamp and position of the test-plate.

Test 2. This test was made on the round table in a similar manner except that the test-plate was viewed through the photometer from the angle at which a reader might view a sheet of paper placed flat on the table. It may be noted that the reader usually places his book near the edge of the table at which position the effect of regular reflection is practically negligible. Results of measurements in this test follow:

Distance from center of table to test lamp	Angle of view with the horiz.	Horizontal illumination
6 inches	40°	9.6 ft. c.
12 inches	50°	8.9 ft. c.
18 inches	67°	7.2 ft. c.
24 inches	90°	4.8 ft. c.

The foot-candle values obtained in this test are shown on the plan, inscribed in rectangles.

Rectangular Reading Tables.

A plan of one of these tables, showing the location of the two lamps which provide local illumination, is shown in Fig. 29. Horizontal illumination values determined as in test No. 2, of the illumination of the round reading tables, are given upon the

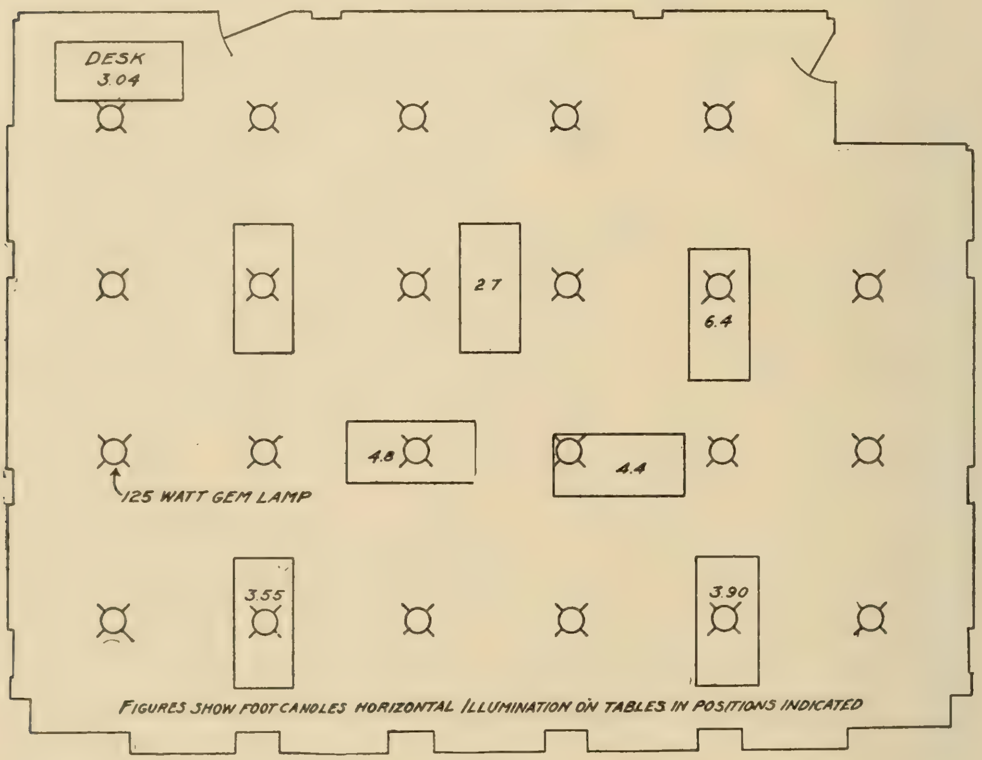


Fig. 31.—Illumination Measurements in Roof Reading Room.

diagram, the angle at which the blotting paper was viewed from the photometer, being in each case approximately 45 degrees above the horizontal.

Roof Reading Room.

These tests were made with the regular illumination attachment of the photometer. Results are shown on the plan (Fig. 31), in terms of foot-candles illumination, the figures showing at the same time, by their position upon the diagram, the location of the test-plate during the test.

FEATURES OF THE DESIGN.

(1) Freedom from glare. No unshaded lamps. Intrinsic brightness of lighting sources, 1/10 of a candle-power per square inch of actual surface.

(2) General illumination combined with localized illumination.

(3) General illumination one foot-candle on horizontal working plane.

(4) Illumination (horizontal) on reading tables, average working conditions, 5 foot-candles.

(5) Illumination (vertical) on bookshelves 1½ to 4 foot-candles.

Illumination (horizontal) on bookshelves 4 to 8 foot-candles.

(6) Combination of general and localized lighting designed to secure maximum illumination on the working spaces at minimum cost of operation for the required results.

Ceiling pendants for general illumination designed for efficient use of tungsten lamps.

(7) Flexibility. Design of switching arrangements for economical use of light. Lights near windows placed on same circuits so far as possible.

(8) Lamps for general illumination hung high but low enough to avoid sharp contrasts on the ceiling.

(9) Lamps for general illumination enclosed in 16 inch crystal glass globes roughed on the outside.

(10) Lamps for table lighting provided with prismatic reflectors designed to throw the maximum light sideways instead of downwards. Frosted lamps used.

(11) Lamps for lighting low bookshelves screened from view by opaque parabolic reflectors. Lamps for lighting wall bookcases, backed by opaque trough reflectors.

(12) Lamps for lighting free standing bookcases and reading tables screened from view by green plated glass domes.

(13) Lamps for lighting exhibition racks screened by reflectors with green celluloid covers.

(14) Wall bracket and column bracket lamps provided with deep enamelled glass diffusing shades of sufficient depth to hide the lamp. Frosted tip lamps.

(15) Cheerful appearance of room.

DISCUSSION.

Mr. N. W. Gifford :—The author gives 5 foot-candles for the illumination on a reading table and I should like to know if that is enough or too much. Is there not a possibility that the popular tendency is to use more light than is absolutely necessary in some places? Of course, generally we do not get enough. I think, however, that the possible tendency, is to give too much light for reading purposes. The matter has been somewhat investigated in school house lighting in Boston by a one-sided commission, which selected a value of 2.5 foot-candles, I believe. After making the report they said that each individual commissioner was not quite sure whether the right value had been chosen.

Mr. V. R. Lansingh :—Were the average of the values given on Fig. 26, used in obtaining the specified lumens per watt, or was the total area divided up into squares and the true average taken?

Mr. P. S. Millar :—The library described in this paper is the only well lighted library which I have ever seen. It is well worth visiting to study the effects produced. I want to express my personal appreciation of the spirit in which this paper is presented. These engineering data placed in our TRANSACTIONS for the benefit of our members are very valuable.

Mr. C. O. Bond :—It seems to me that, as time goes on, this Society will have to accumulate data of this kind which will eventually form a complete text-book for illuminating engineers. Illuminating engineers are certainly largely responsible to the next generation as to whether they shall wear glasses, be short-sighted or otherwise visually deficient. There is no place in which to begin so good as the public schools and libraries. Public schools are illuminated very largely by daylight, and the burden of failure in this respect will fall largely on the architect. The case of the library, is different ; school children, who may do their reading there, will probably do it mostly in the evening by artificial light. This lighting problem is therefore of the utmost importance, and I think every member of this Society who finds himself in New York would do well to visit this library and witness the success to which Mr. Millar has testified. If the Illuminating Engineering Society stands for anything, it stands

for the preservation of that best of all of the God given five senses—the sight.

I have sometimes thought that we might have a better name for this organization than "The Illuminating Engineering Society," and say openly that it is a society for the preservation of human eyesight, and we should move forward and take that wide ground, wide enough to allow untechnical people to come in as members of this Society also, as is clearly set forth in the Constitution and By-Laws, where it is stated that "a member may be anyone interested in the objects of the Society." For this reason unless we include educational papers as well as technical papers, we shall fail in our mission. I say this, because there is among some members a feeling that merely educational papers should be barred from the TRANSACTIONS, if not from Section meetings. In my opinion, there is nothing that will be so beneficial to the Society in promoting its growth as educational papers. I dare say that in our midst there cannot be found ten men fully qualified to understand the technical discussions which take place, while we find ninety who are earnest and willing, but as yet cannot comprehend such discussions, and I personally am well down among the ninety.

We should make the work of the Society such that the people generally will join with us. I think Mr. Marks deserves the thanks of this Society for having been its able exponent in this way.

Mr. L. B. Marks :—With regard to the proper amount of illumination on the reading tables, there is some question. I investigated the conditions in the New York Public Libraries for a period of six months before attempting the illumination design, and came to the conclusion that 2.5 foot-candles under average working conditions is not nearly enough for some of the readers who frequent the libraries. There is a wide class of readers of various ages and conditions of eyesight. The print in some of the books and journals is fine and becomes more or less obscured through frequent handling of the pages. Some of the books are printed in foreign languages.

The design of the illumination is such that the reader may so place his book or other reading matter as to receive as high as 10 foot-candles or as low as 1 foot-candle, as evidenced by the tests. Near the edge of the table, in which location the book is

perhaps more frequently placed than in any other, the illumination is about 5 foot-candles when the book is flat on the table. Just outside the edge of the table the illumination is considerably less than this.

The book shelves must have a high degree of illumination, to enable the reader to decipher easily the titles of books without removing them from the shelves and to permit of local casual inspection of the contents of the books.

An important problem which came up for consideration in working out this design was that of general illumination versus localized illumination. It was decided that the best results in illumination for this case—intensity of illumination, economy, low intrinsic brightness, etc. being considered—could be secured only by a moderate general illumination supplemented by localized illumination on the working spaces.

With regard to Mr. Gifford's question, as pointed out by me, the illumination of the school room is quite a different proposition from that of public library lighting. An illumination that would be satisfactory in a school might not be at all adequate in a library in which the conditions that I have described prevail.

With regard to Mr. Lansingh's question, I pointed out in the paper that the value for the average foot-candles on the horizontal working plane was ascertained by taking the average of the illumination values given on the chart, Fig. 26. The test stations were not located with a view to equal spacing, but to represent the working spaces throughout the room. From this average value the lumens per watt, or foot-candles per watt per square foot were calculated. It is the value obtained by averaging the illumination values which were observed at the building but it is not the average value for the whole area. The value of the foot-candles per watt per square foot, measured in this way, would still compare quite favorably with the true average for prismatic reflectors and exposed carbon-filament lamps. The point is that it is possible to enclose the lamps entirely in diffusing globes as in the present library installation, and still obtain very good efficiency.

President Bell:—The Society owes a debt of gratitude to Mr. Marks for placing the data contained in his paper before his colleagues.

THE INTRINSIC BRIGHTNESS OF LIGHTING SOURCES[1]

BY J. E. WOODWELL.

The importance of intrinsic brightness as a factor in practical illumination has been long appreciated and strongly emphasized. At no time has this factor been more essential from the standpoint of hygiene of the eye than the present. The opportunities for violation of the laws of hygiene have not only been enlarged, but the penalties of such abuses have been greatly augmented, with the general introduction of the more recently developed lighting sources of high intrinsic brightness, such as the metallic filament incandescent lamps, flaming arc lamps and high pressure gas lamps. In too many of the recent installations the most dazzling gas and electric lamps are ruthlessly placed in such positions that the eye cannot escape the glare. Moreover, the distressing brightness of the source is often intensified by the improper use of concentrating reflectors.

The physiological and hygienic effects of the intrinsic brightness of luminous sources on the visual organs has been ably presented by specialists in papers[2] read at previous meetings of the Society, so that reference to this phase of the subject will be confined to such points as have a direct bearing upon the practical design of illumination.

Briefly, any brilliant source of light in the field of view, however small, causes a contraction of the pupil of the eye and reduces the effect of illumination received from other parts of the visible field. A contraction of the pupil also takes place even if the bright spot is viewed only occasionally. Furthermore the continuous or occasional presence of a bright light source in the field of view impairs, temporarily at least, the sensitiveness of the eye itself, thus again reducing the effectiveness of illumi-

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908

[2] "Some Physiological Factors in Illumination and Photometry," Dr. Louis Bell; "Light and Illumination," Charles P. Steinmatz; "Matters of Illumination Which Affect the Eye," Dr. Wendell Reber; "Effect of Light upon the Eye," Dr. H. H. Seabrook; "Eyesight and Artificial Illumination," Dr. John T. Keall; Artificial Illumination from a Physiological Point of View," Dr. Myles Standish.

nation. Moreover the contraction of the iris in the presence of bright light sources soon reaches the limit of its protective faculty, beyond which it responds feebly to an increase in brightness. The control of the pupillary aperture appears to be designed to strengthen the vision under comparatively weak illumination, rather than to protect against excessive intensity or brightness.

Recent researches of André Broca and F. Laporte[1] indicate that the pupillary contraction caused by bright light sources within the peripheral vision reduces visibility in proportion to the decrease in working illumination and produces the greatest eye fatigue in comparatively weak illumination. The exhaustion and injurious effect was greatly reduced on the other hand under an illumination of from 1.86 to 3.72 foot-candles which was shown by tests to be favorable for work, taking into consideration the physiological properties of the eye and the mean limits of its accommodation.

The *intrinsic brightness* of the luminous source rather than the *distance* of the source from the eye was shown to be the principal cause for pupillary contraction. This same careful investigation also made it evident that the different light sources may be classed—with reference to their action in producing pupillary contraction and residual images—in the order of their respective intrinsic brightness.

The researches referred to above as well as other previous investigations do not indicate that the protective faculty of the eye is susceptible to the energy effect or to light rays of different color.

Ultra violet rays have been regarded by some authorities as harmful, but it has been shown that these rays in the light from various forms of incandescent illuminants of high intrinsic brightness are with few exceptions, much less than in direct or even reflected sunlight. Other invisible radiation of much more harmful character may accompany not only the newer light sources of high incandescence but those of lower temperature as well.

The more important hygienic effects of light sources of high

[1] Étude des principales sources de lumière au point de vue de l'hygiène de l'oeil. MM. André Broca et F. Laporte. *Bulletin* of the Société Internationatle des Électricians, Vol. VIII (2nd series), No. 76.

intrinsic brilliancy within the field of vision may then be summarized as follows :

1. Contraction of the pupil is caused, thereby reducing the amount of light entering the eye and the consequent visbility.

2. The sensibility of the visual organs is temporarily impaired by residual images and retinal fatigue.

3. The effects of (1) and (2) are also produced by the occasional view of bright sources or by subjecting the eye to sudden fluctuations of light.

4. *Intrinsic brightness* rather than the *distance* of the source from the eye is the principal cause for pupillary contraction.

5. The harmful effects are greatest in proportion to the decrease in the working illumination and are considerably reduced under an illumination exceeding 2 foot-candles.

6. The different luminous sources may be classed with reference to producing pupillary contraction and after-images in the same order as their respective intensities.

In applying the knowledge to the laws of hygiene of the eye to the design of artificial illumination, the best criterion of the proper values of intrinsic brightness of the light source, as well as of other essential factors, is daylight.

The intrinsic brightness of nearly all of the artificial light sources being so much higher than that of natural daylight is the principal cause of eye-strain and wear and tear on the visual organs. Even the most successful efforts to secure diffusion in artificial illumination by the so-called indirect method cannot be compared with the diffusion of daylight. From this point of view *diffusion* is the most important single quality of daylight. Diffusion may be obtained in artificial illumination by enlarging the area or surface of the light source, by shading the source with diffusing globes or screens, or by concealing the source and utilizing the diffuse reflection of the surfaces which receive the direct light.

Whatever method may be applied in practice to secure improved diffusion and reduced intrinsic brightness of the artificial sources, it is most important to determine the values of intrinsic brightness which are both safe and advantageous to apply to the design of illumination.

The intrinsic brightness of a light source is the candle-power

or *intensity of* the source divided by the *area* of the luminous surface. The intrinsic brightness of a small surface is the candle-power perpendicular to the surface divided by the area of the surface. Intrinsic brightness is stated, therefore, in candle-power per square inch, or in Hefners per square centimeter when metric units are employed.

Admitting the qualities of daylight to be the proper criterion for the factors of artificial illumination, one is confronted with the problem of determining the virtual intrinsic brightness of the flux of light received through a window or skylight from the sky under the variations imposed by nature.

Measurements taken by Basquin show a mean annual brightness for zenith sky in Chicago of 500 candles per square foot, or about 3.47 candles per square inch, with a range from 200 to 1100 candles per square foot according to the month and other conditions. Making due allowance for the decrease in brightness near the horizon for natural reasons, and the reduction of the effective sky area by buildings and other local objects, the virtual intrinsic brightness of the sky in relation to the flux of light received through an ordinary vertical window, under average conditions probably rarely exceeds one-fourth of the above figure.

Measurements of the daylight illumination received in rooms at various distances from a window fitted with a ground glass screen indicate also that the virtual brightness of the flux of light from the sky, direct sunlight excluded, though varying widely under different conditions, is not often more than one candle-power per square inch. Even such a comparatively low degree of brightness exposed to view affords discomfort to the eye. Shades and screens are depended upon to modify all but the most moderate natural brilliancy so that with a satisfactory interior illumination the virtual intrinsic brightness of the flux of daylight through windows may be as low as 0.1 or even 0.01 candle-power per square inch.

Even an abnormally high illumination of 10 foot-candles on a white diffusing surface, such as white blotting paper, gives an intrinsic brightness of the surface, figured as a flat source of secondary illumination, very little more than 0.02 candle-power per square inch, neglecting absorbtion which would reduce the apparent brightness to 0.016 candle-power or less.

Compared with such figures the intrinsic brightness of all of the naked artificial luminous sources is enormously high, while the values secured in practice by the use of shades and diffuse reflecting surfaces are generally more than ten times as great.

A number of authorities regard four or five candle-power per square inch safe and admissible and one or two candle-power good practice. While the use of even the lower of these values in artificial illuminations is questioned, it would result in a most pronounced improvement from the hygienic standpoint and alleviate one of the principal causes of eye strain and fatigue.

Acid-frosted or sand-blasted incandescent carbon or metallized filament lamps as commonly used in exposed positions without reflectors have an intrinsic surface brightness of from 0.75 to 1.0 candle-power per square inch. When in the field of vision however, such frosted lamps frequently produce a most distressing and harmful result, and reduce the value of the effective illumination.

In consideration of the foregoing data, as well as from actual experience in the design of illumination, it is the opinion of the writer that from 0.2 to 0.1 candle-power per square inch of diffusing surface, is none too low for the safest and best practice where artificial sources must necessarily be placed in the constant or even occasional field of vision. The use of such a factor is necessarily dependent upon the local conditions and especially upon the intensity of general illumination of the objects viewed and the corresponding pupillary aperture, as noted by Broca and Laporte.

In the presence of a highly illuminated field of view the iris diaphragm of the eye is "stopped" down almost to a minimum, and the direct effect of any light sources within the field of vision is correspondingly lessened. These conditions occur in practice where a room or space is almost uniformly illuminated by exposed lighting sources of high brilliancy and there are neither dark surfaces, sharp contrasts nor shadows which would require the eye to work with a larger pupillary aperture. Such conditions, while tending to reduce the deleterious effect of brilliant light sources, are not the most favorable for best vision. Working in such an environment it is not strange that a comparatively high intensity of illumination in foot-candles is frequently demanded and the eye appears insatiable. From the standpoint of

efficiency, therefore, as well as of hygiene the conditions must favor a pupillary aperture which is sufficiently large to work the eye at its maximum sensibility. To accomplish this result the intensity of illumination should not only be moderate, in general from 1.5 to 4 foot-candles, but the intrinsic brightness of the sources should be reduced to 0.2 or 0.1 candle-power per square inch of diffusing surface ; or else the sources must be completely excluded from the field of vision.

With a weak illumination, however, requiring the eye to work at or near the limit of opening of the pupillary aperture the eye is extraordinarily sensitive to the direct light from sources of even moderate intrinsic brightness, and under such circumstances the actual apparent surface brightness of the source cannot be kept too low for safety. This point is illustrated by the distressing effect of frosted and shaded lamps, and sometimes of candles, in the field of vision under the conditions of a weak general illumination frequently found in theatres, churches and auditoriums.

It is possible that the effects of over-stimulation by means of varying intrinsic brightness has some such relation to the pupillary aperture through the range of accommodation of the eye as that of the ability of the eye to note a constant fractional difference in luminosity through a wide range of intensities of illumination, according to the law of Fechner.

The distance of the luminous source from the eye within the limits ordinarily found in interior illumination does not appear to be material, except in its relation to the position of the source and its inclusion or exclusion of the field of vision.

The preceding discussion has been confined to the direct effects and modification of the intrinsic brightness of luminous source, but it is evident that the same conditions will apply equally well to the reduction of the intrinsic brightness of all illuminated surfaces which become secondary sources of illuminations. Even with indirect illumination the ratio of brightness of the reflecting surfaces to that of the illuminated field may be excessive.

The foregoing data will have their principal application, however, in the design of globes and shades which are commonly employed to reduce the intrinsic brightness of exposed lighting sources. In arriving at the resultant intrinsic brightness it is necessary to refer to the spherical candle-power of the source and

to make allowance for the absorption by the glass which may vary between from 15 to 25 per cent. for alabaster to 60 per cent. or more for opal or porcelain glass. The absorption by ground glass will vary according to the process employed in roughing or sand blasting, but it will generally be between 20 and 40 per cent. The thickness as well as the quality of the glass will also have a marked influence upon the absorption. Moreover the distribution of the light from this source will be modified by surrounding the lamp with an inclosing globe. The most perfect diffusion will be received by a ground opal glass, but at a sacrifice of from 40 to 60 per cent. of the total light. The more transparent glasses, on the other hand, do not sufficiently diffuse the light from the source. In any event however, it is important that the size of the diffusing globe or shade should be proportioned to the candle-power of the source, so that the reduction of intrinsic brightness will be approximately uniform. Fixture designs employing exposed frosted lamps together with other lamps in large inclosing globes of comparatively low intrinsic brilliancy are especially objectionable.

The rules and factors which are applied to inclosing globes have equal force when applied to prismatic or other open shades having a sand-blasted or enamelled diffusing surface.

In conclusion, it is probably unnecessary to state that this paper treats merely of certain practical aspects of the factor of intrinsic brightness of luminous sources in the most preliminary way. So much depends upon the actual working conditions and requirements that no hard and fast rules or specific data can be given which can be applied without modification in practical artificial illumination. The technology of the subject is worthy of extended development and research.

The most essential point is to reduce the intrinsic brightness of all sources within the field of vision to not over 0.2 candle-power per square inch of diffusing surface.

DISCUSSION.

President Bell:—I am particularly glad to note from the work referred-to in the report that the pupil's contraction is actually and practically a function of the intrinsic brilliancy. I have always argued that relation in discussing the matter of general

principles, based on experimental data, and I am extremely glad to have it confirmed.

Mr. D. McFarlan Moore:—I am pleased to note that gradually the Society is giving its specific attention to the half dozen or so vital factors in any system of lighting, including color and intrinsic brilliancy. A few years ago a convention of this kind probably would not have given attention to two such matters as color and intrinsic brilliancy.

Mr. Woodwell's statement that the intrinsic brightness rather than the distance of the source from the eye is the cause for the pupil's contraction is illustrated in exterior lighting in a remarkable way. I refer to the lighting of large fairs. When the buildings in the fair grounds are outlined, for example, with incandescent lamps, one arc lamp, even a quarter of a mile distant, but in the range of vision, spoils the entire effect and must be removed in order to make the exhibit of incandescent lighting what the illuminating engineer intended it to be.

It is noteworthy that the theoretical specifications as indicated in this paper are met by only one source of lighting directly. I refer to the vacuum tube. That is to say, all other forms of lamp, and I think there are no exceptions, naturally *generate* light initially at intrinsic brilliancies far in excess of daylight as a standard, and far in excess of the values stated in the paper. In the case of the vacuum-tube, however, the brilliancy of the light can be regulated over a very wide range, but it is always *generated* at the intensity at which it is to be used. This point is one of great importance.

The recent advances that have been made in the various forms of incandescent lamps have been due largely to increasing the intrinsic brilliancy. Such lamps are not fit to be used until they are enclosed in some form of diffusing globe, which, as the paper suggests, may consume 60 per cent of the light.

This society should secure more data as to the relative efficiencies of various systems of illumination under the conditions in which they are normally used.

In a comparatively recent paper before the American Institute of Electrical Engineers I stated that when a vacuum tube, 1.75 inches in diameter, was operated at six hefners per foot, or 0.33 candle-power per square inch, it produced a remarkable amount of use-

ful illumination from an apparently very dim source. These figures are intensely interesting in connection with the tungsten lamp which has an intrinsic brilliancy of about 2000 candle-power per sq. in. In other words, an average vacuum tube of one two thousandths its intensity, will produce an equal illumination.

Mr. Carl Hering:—Mr. Woodwell has anticipated a criticism I was going to make, by changing a certain numerical value in his paper, to which I called his attention yesterday. I think it well however to lay some stress on this point, because I think the error which he had made in his paper has also been made by many others. I refer to the method of calculating the candles per square inch. In his paper, as originally stated, he has divided the candle-power by the *total* area of the globe. Now that method, in my opinion, is wrong, as he has acknowledged by changing it to the "projected" area. For a globe this makes a change to four times the value obtained, which is too large to be overlooked. Some of the figures given in the paper should therefore be multiplied by four.

The same mistake has apparently been made in the earlier literature, in which the candles per square inch were calculated by dividing the candle-power by the total area ; it is only the projected area, and not the total area, which should be used. I go a step further than he does and claim it is actually wrong to calculate it the other way. It is not a question of preference, but a question of which is the right way.

I would like to take this opportunity to endorse a statement which he make to the effect that sometimes with a weaker illumination one can see better than with a stronger, if in the latter case the eye is exposed to some glaring light in front of it. I made that statement many years ago, before a prominent society, and was ridiculed. I was told that the photometer was the only proper means of measuring light for seeing things, and I am glad to learn that it is being recognized now that the eye too has a great deal to do with it. The question is not one solely of photometry, but of the distribution of light as well.

Mr. V. R. Lansingh:—It seems to me there is another side to this question which should be brought out. It is not, in my opinion, simply the intrinsic brilliancy or candle power per square inch, but also the total amount of light. With a large

area of low intrinsic brilliancy, the effect may be just as hard on the eyes as a smaller source of high intensity. In the case, for example, of the mercury-vapor lamp, with an intrinsic brilliancy of only nineteen candle-power per square inch, the effect is extremely trying on the eye, although the intensity is comparatively low. This is due to the fact that the tube is so long that the quantity of light is very large. I think both of these things must be taken into account in order to protect the eye.

Mr. J. E. Woodwell:—Mr. Moore referred to the loss of 60 per cent. in enclosing a lamp within a globe. That loss represents a possible limit under certain conditions which might arise, and in some cases that loss might be fully justified. However, it is not necessary in the majority of cases, to make such a sacrifice, and 25 or 30 per cent. maximum would more properly represent the loss by enclosing the lamp in a diffusing globe.

Regarding Mr. Hering's point, I think it is a matter of definition and conception of the phrase "intrinsic brightness." I understand the word "intrinsic" to mean *actual* brightness. I further understand the definition of the phrase as used by the Geneva Congress to mean the intensity, measured in a direction normal to the surface, per unit area. If the entire surface of the sphere is taken as I have done, I think it falls within the conception of that definition just as fully as the projected area which Mr. Hering advocates.

I have been unable to refer to the definition itself, but base my knowledge upon the quotations which have been made of that definition which have appeared in current literature. It is a matter to which I am somewhat indifferent, because the point of the paper was to emphasize the great importance of reducing the intrinsic brightness of lighting sources, from a physiological point of view.

If both of the comparative values given in my paper are multiplied by four, the same relation holds and the point is proven that the intrinsic brightness of all our artificial sources must be greatly lowered.

The matter of the absolute definition of intrinsic brightness should come to the attention of the Committee on Nomenclature and Standards, along with some of the other conceptions which were brought up in Mr. Hering's paper.

Mr. Lansingh's point, as to the effect of quantity, is a matter upon which there should be considerable research to determine the actual physiological effect. It is not clear to me how the effect of two sources of the same brightness but of different size or area differ though the larger one may impinge more fully on the surfaces of the retina. Where there are multiple sources, in view, the effect may be likened to a bombardment of bird shot, compared with a single bullet. The cells of the eye are broken down by a bombardment from the numerous or large sources of light impinging on the retina.

SOME EXPERIMENTS ON REFLECTIONS FROM CEILING, WALLS AND FLOOR.[1]

BY V. R. LANSINGH AND T. W. ROLPH.

The tests described below were undertaken to determine the values of the reflection of light from ceiling, walls and floor under average conditions of artificial lighting. To obtain these values actual measurements of illumination were made

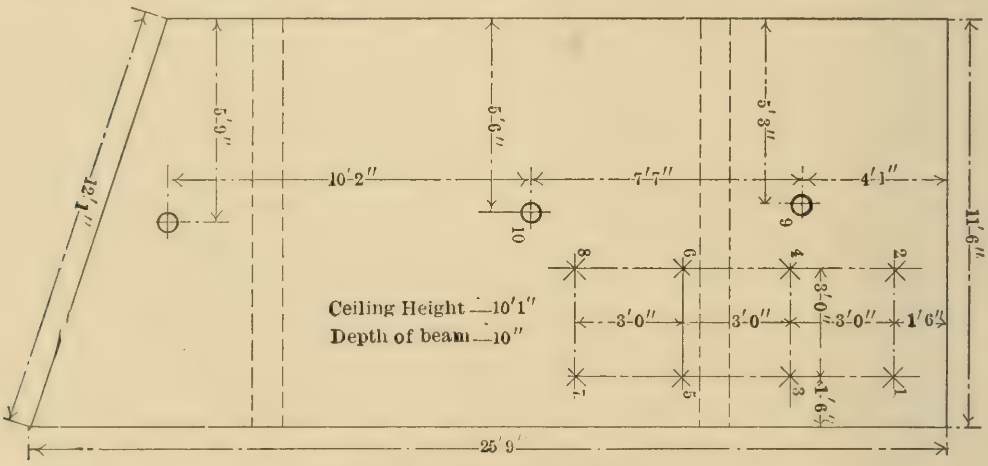


Fig. 1.—Plan of Test Room.

with each of the eight possible combinations of light and dark ceiling, walls and floor. The tests were carried on during the afternoon and evening of July 23, 24 and 29, 1908.

The results of the tests, as taken up in this paper comprise three parts:—

(1)—Analysis of the values of increase in illumination under various conditions; (2)—Analysis of the effect of reflection on uniformity of illumination; (3)—Determination of the angle below which lumens generated are lumens effective.

TEST ROOM.

The room selected was 24 ft. 3 in. long, 11 ft. 6 in. wide and 10 ft. 1 in. high. It was not quite rectangular in shape, one end sloping so that the maximum length was 25 ft. 9 in. and the minimum was 22 ft. Three outlets were located as shown on plan of Fig. 1. The walls were lined with dark green burlap.

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, October 5-6, 1908.

The floor was nearly covered by dark green rugs and the uncovered part was stained a dark cherry color. Three doors in the walls were stained a dark cherry color. There were no windows in the room. For the experiments with light ceiling, walls or floor, use was made of a lining of light cream-colored wrapping paper.

LAMPS AND REFLECTORS.

The lighting units employed were 40-watt, 115-volt, tungsten lamps, and the reflectors were of the prismatic equal prism type The reflectors were built to give what is termed the bowl distribution and were of a new design recently introduced. The light units in each case were placed close to the ceiling, the socket being approximately flush.

After the test had been completed, it was found that better results might have been obtained by using 100 watt lamps, as higher illumination values would have resulted. This fact is stated for the benefit of those making tests of this nature in the future.

INSTRUMENTS.

The instruments used were as follows:—

A Sharp-Millar photometer with a 112-volt standard lamp; a Weston alternating and direct voltmeter for obtaining the voltage of the line at each reading; a Weston milli-voltmeter calibrated as an ammeter for maintaining the standard lamp at the proper amperage.

METHOD OF TEST.

Assuming the room rectangular and the outlets approximately equally spaced, one-quarter of the room was divided into eight equal squares, each having a side of 3 ft. A station was placed at the center of each square. The average of these eight readings should therefore give the average illumination in the room. Additional stations Nos. 9 and 10 were placed under two units as shown on plan (Fig. 1), since these values are of interest. Illumination readings were taken at a height of 2.5 ft. above the floor. Two readings were taken at each station, and if these did not agree closely a third or fourth was taken. The mean of all the readings taken at each station was considered the illumination value at that station. Illumination and voltage reading were made simultaneously.

Tests were conducted under the following conditions:—

One lamp bare in center of room,

Test No. 1—Ceiling, walls and floor dark
" " 2—Ceiling light, walls and floor dark
" " 3—Ceiling and walls light, floor dark
" " 4—Ceiling, walls and floor light
" " 5—Walls light, ceiling and floor dark
" " 6—Walls and floor light, ceiling dark
" " 7—Floor light, ceiling and walls dark
" " 8—Ceiling and floor light, walls dark.

Tests Nos. 9 to 16, with the same conditions as tests Nos. 1 to 8, except that a bowl reflector was placed on the lamp.

Tests Nos. 17 to 24, with the same conditions as tests Nos. 1 to 8, except that three bare lamps were used.

Tests Nos. 25 to 32, with the same conditions as tests Nos. 1 to 8, except that bowl reflectors were used on three lamps.

CORRECTIONS.

After the test, the illuminometer with its ammeter was calibrated at the Electrical Testing Laboratories. A standard lamp was used for this and calibration readings were observed by Mr. Rolph, who made all the readings in the test. The correction factor obtained should therefore eliminate the personal equation.

The voltmeter was also calibrated and voltmeter readings were corrected accordingly. After correcting the illumination readings for the error of the illuminometer, they were again corrected in the three-lamp tests to correspond to the rated voltage of the lamps producing the illumination. These corrections were made by means of the candle-power-voltage characteristic of the tungsten filament. The characteristic was obtained from the Engineering department of the National Electric Lamp Association.

In the one-lamp tests the readings were corrected to correspond to the voltage at which each of the lamps gave 32 mean horizontal candle-power. This was done for the following reason:—The tests for the horizontal candle-power of the lamps showed that the clear lamp used in the one-lamp tests gave 34.1 mean horizontal candle-power at 115 volts, while the frosted tip lamp gave 30.4 mean horizontal candle-power at 115 volts. From the data which the authors were able to obtain, compar-

ing the mean horizontal candle-power of clear and frosted tip lamps, it appears that the ratio varies considerably, with some lamps being positive and with others being negative. The value of 1.0 is, therefore, probably very nearly correct. The clear lamp used in the test showed a mean horizontal candle-power 12 per cent. higher than the frosted tip lamp. This value is entirely too high for lamps giving the same mean spherical candle-power and it is, therefore, considered fair to reduce the values to the equivalent of lamps giving the same mean horizontal candle-power. It should be noted that this does not effect the comparative values where the same lamp is used but only those where tests with the bare lamp are compared with tests with the lamp and reflector.

CANDLE-POWER TESTS OF TUNGSTEN LAMPS OPERATED AT RATED VOLTAGE OF 115.

Lamps	M. H. C. P.	Watts	Watts per C. P.
Clear No. 1	30.8	39.4	1.28
" " 2	34.1	38.9	1.14
" " 3	31.9	38.4	1.20
Fr. Tp." 1	33.3	39.8	1.20
" " 2	30.4	38.2	1.26
" " 3	29.8	38.4	1.29

TESTS NOS. 1-8 INCLUSIVE.

One bare, clear 40-watt, 115-volt tungsten lamp on ceiling.

Conditions:—

Test No. 1—Ceiling, walls and floor dark.
" " 2—Ceiling light, walls and floor dark.
" " 3—Ceiling and walls light, floor dark.
" " 4—Ceiling, walls and floor light.
" " 5—Walls light, ceiling and floor dark.
" " 6—Walls and floor light, ceiling dark.
" " 7—Floor light, ceiling and walls dark.
" " 8—Ceiling and floor light, walls dark.

Total illumination in foot-candles:

Station	Test No. 1	Test No. 2	Test No. 3	Test No. 4
1	.09	.12	.35	.44
2	.10	.14	.36	.44
3	.14	.22	.43	.56
4	.17	.24	.49	.55
5	.22	.37	.59	.78
6	.30	.51	.68	.83
7	.26	.50	.72	.90
8	.26	.63	.83	.91
9	.17	.25	.48	.59
10	.18	.64	.89	1.01
Mean (Stations 1-8)	.19	.34	.56	.68
Maximum variation from mean	+ 58% (Station 6)	+ 88% (Station 10)	+48% (Station 10)	+ 49% (Station 10)

Station	Test No. 5	Test No. 6	Test No. 7	Test No. 8
1	.21	.25	.09	.13
2	.23	.25	.11	.17
3	.26	.28	.14	.25
4	.29	.30	.18	.28
5	.35	.35	.25	.40
6	.35	.40	.32	.52
7	.41	.42	.29	.49
8	.42	.45	.28	.65
9	.26	.28	17	.30
10	.34	.32	.22	.64
Mean (Stations 1-8)	.31	.34	.21	.37
Maximum variation from mean........	36% (Station 8)	32% (Station 8)	— 57% (Station 1)	76% (Station 8)

Tests Nos. 9-16 Inclusive.

One 40-watt, 115-volt, frosted tip tungsten lamp, with prismatic reflector. Unit close to ceiling.

Conditions: —

Test No. 9—Ceiling, walls and floor dark.
" " 10—Ceiling light, walls and floor dark.
" " 11—Ceiling and walls light, floor dark.
" " 12—Ceiling, walls and floor light.
" " 13—Walls light, ceiling and floor dark.
" " 14—Walls and floor light, ceiling dark.
" " 15—Floor light, ceiling and walls dark.
" " 16—Ceiling and floor light, walls dark.

Total illumination in foot-candles:

Station	Test No. 9	Test No. 10	Test No. 11	Test No. 12
1	.08	.13	.26	.47
2	.09	.14	.27	.47
3	.15	.24	.37	.55
4	.25	.36	.47	.63
5	.36	.47	.65	.93
6	.58	.74	.87	1.30
7	.53	.70	.94	1.30
8	.87	1.08	1.21	1.57
9	.22	.28	.42	.65
10	.82	1.08	1.21	1.62
Mean (Stations 1-8)	.36	.48	.63	.90
Maximum variation from mean........	142% (Station 8)	125% (Station 8 and 10)	92% (Station 8 and 10)	80% (Station 10)

Station	Test No. 13	Test No. 14	Test No. 15	Test No. 16
1	.15	.21	.09	.14
2	.16	.22	.10	.16
3	.25	.28	.18	.25
4	.28	.32	.25	.31
5	.44	.47	.38	.48
6	.64	.65	.55	.76
7	.65	.71	.58	.75
8	.89	1.02	.82	1.07
9	.28	.31	.22	.29
10	.83	.93	.77	1.07
Mean (Stations 1-8)	.43	.49	.37	.49
Maximum variation from mean........	107% (Station 8)	108% (Station 8)	122% (Station 8)	118% (Station 8 and 10)

TESTS NOS. 17-24 INCLUSIVE.

Three clear, bare 40-watt, 115-volt tungsten lamps on ceiling.

Conditions :—

Test No. 17—Ceiling, walls and floor dark.
" " 18—Ceiling light, walls and floor dark.
" " 19—Ceiling and walls light, floor dark.
" " 20—Ceiling, walls and floor light.
" " 21—Walls light, ceiling and floor dark.
" " 22—Walls and floor light, ceiling dark.
" " 23—Floor light, ceiling and walls dark.
" " 24—Ceiling and floor light, walls dark.

Total illumination in foot-candles :

Station	Test No. 17	Test No. 18	Test No. 19	Test No. 20
1	.37	.68	1.30	1.70
2	.41	.85	1.47	2.02
3	.40	.77	1.44	1.82
4	.48	1.07	1.75	2.05
5	.49	.89	1.56	1.95
6	.62	1.15	1.75	2.13
7	.51	.89	1.55	1.89
8	.54	1.19	1.74	2.11
9	.39	.98	1.62	2.11
10	.44	1.14	1.73	2.05
Mean (Stations 1-8)	.48	.94	1.57	1.96
Maximum variation from mean........	29% (Station 6)	—28% (Station 1)	—17% (Station 1)	—13% (Station 1)

Station	Test No. 21	Test No. 22	Test No. 23	Test No. 24
1	.77	.84	.39	.69
2	.82	.88	.44	.92
3	.81	.93	.42	.86
4	.84	.92	.50	1.17
5	.87	.95	.50	.95
6	.96	.99	.64	1.25
7	.86	.91	.52	.92
8	.87	.95	.58	1.20
9	.75	.81	.41	1.06
10	.78	.84	.46	1.15
Mean (Stations 1-8)	.85	.92	.50	.99
Maximum variation from mean........	13% (Station 6)	—9% (Station 1)	28% (Station 6)	26% (Station 6)

TESTS NOS. 25 to 32 INCLUSIVE.

Three 40-watt, 115-volt, frosted tip tungsten lamps with prismatic reflectors. Units close to ceiling.

Conditions :—

Test No. 25—Ceiling, walls and floor dark.
" " 26—Ceiling light, walls and floor dark.
" " 27—Ceiling and walls light, floor dark.
" " 28—Ceiling, walls and floor light.
" " 29—Walls light, ceiling and floor dark.
" " 30—Walls and floor light, ceiling dark.
" " 31—Floor light, ceiling and walls dark.
" " 32—Ceiling and floor light, walls dark.

Total Illumination in foot-candles :

Station	Test No. 25	Test No. 26	Test No. 27	Test No. 28
1	.53	.70	1.33	1.60
2	.89	1.14	1.85	2.32
3	.72	.92	1.51	1.99
4	1.14	1.51	2.02	2.51
5	.72	.99	1.61	2.02
6	1.31	1.66	2.06	2.81
7	.77	.91	1.58	2.28
8	1.20	1.56	1.98	2.60
9	1.10	1.46	2.00	2.49
10	1.05	1.43	1.87	2.53
Mean (Stations 1-8)	.91	1.17	1.74	2.27
Maximum variation from mean........	44% (Station 6)	42% (Station 6)	—26% (Station 1)	—30% (Station 1)

Station	Test No. 29	Test No. 30	Test No. 31	Test No. 32
1	.82	.92	.54	.81
2	1.22	1.32	.97	1.19
3	.98	1.06	.69	.93
4	1.40	1.44	1.16	1.38
5	.99	1.07	.74	.99
6	1.42	1.46	1.16	1.62
7	.99	1.09	.77	1.08
8	1.33	1.47	1.11	1.60
9	1.36	1.44	1.09	1.51
10	1.42	1.44	.98	1.45
Mean (Stations 1-8)	1.15	1.23	.90	1.20
Maximum variations from mean........	—29% (Station 1)	—25% (Station 1)	—40% (Station 1)	35% (Station 6)

CALCULATED ILLUMINATION.

These values are calculated from the photometric curves of the light sources and figured for a height of 7.5 feet above the plane of illumination used in the test. For the one-lamp test the photometric curves were obtained with the lamp at 32 mean horizontal candle-power, since the tests were corrected to this condition. For the three-lamp tests the photometric curves were obtained at 115 volts, which is the conditions to which the illuminometer readings were corrected, in these tests.

After the mean horizontal candle-power of frosted tip lamp No. 3 had been obtained, the filament was accidentally broken. Lamp No. 2 which had approximately the same position of filament was therefore tested with reflector No. 3 at the candle-power which lamp No. 3 gave. This change should not introduce an appreciable error.

Illuminations in foot-candles:

Station	One lamp bare	One lamp with reflector	Three lamps bare	Three lamps with reflectors
1	.088	.094	.32	.56
2	.10	.11	.34	.82
3	.13	.19	.38	.75
4	.16	.27	.39	1.02
5	.19	.36	.44	.79
6	.22	.58	.50	1.23
7	.21	.56	.46	.84
8	.20	.72	.47	1.11
9	.16	.25	.33	.98
10	.14	.61	.40	.83
Mean (Stations 1-8)	.16	.36	.41	.89
Maximum variation from mean	—45% (Station 1)	100% (Station 8)	—22% (Station 1)	26% (Station 6)

In the one-lamp tests an attempt was made to ascertain the direct illumination by measurements as well as by calculation. This was done by taking a second set of readings at each station with the illuminometer disc screened from the direct rays of the light source. These readings would give the indirect illumination, and subtracted from the total the results would be the direct illumination. It was found that the results obtained at the stations farthest from the light source agreed closely with the calculated illumination. The results at the stations near the light source however were so much higher than the calculated illumination that all of the readings were rejected as of no value. The high values obtained show that in the screening process too much reflected light was shut off with the direct light.

Use was made of a square screen about four inches in diameter held at from three to four feet from the illuminometer disc. The authors did not have time to carry this experiment out with greater refinement. It is evident that if this method of obtaining indirect illumination is used, a circular screen should be employed and great care taken that the shadow of the screen covers the illuminometer disc and nothing more. Even then it is doubtful whether reliable results can be obtained when the ceiling is light.

ANALYSIS OF THE VALUES OF INCREASE IN ILLUMINATION UNDER VARIOUS CONDITIONS.

The increase over the direct illumination produced by reflection from dark ceiling, walls and floor, cannot be analyzed in detail as there is no method of separating that due to walls from that due to ceiling, etc. The increase over the illumination with dark ceiling, walls and floor produced by making these light in color can be analyzed. For convenience the increase may be divided into 7 parts which are designated here as N_1,N_2, etc.

Let N_1 = Increase due to ceiling alone
N_2 = “ “ “ walls “
N_3 = “ “ “ floor “
N_4 = Additional increase due to interaction of ceiling and walls
N_5 = “ “ “ “ “ “ “ “ floor
N_6 = “ “ “ “ “ “ walls and floor
N_7 = “ “ “ “ “ “ ceiling, walls and floor.

All percentage values of N represent increase in illumination over test No. 1, in which ceiling, walls and floor were dark.

Analyzed for one lamp bare, the following results are obtained:

Per cent. increase over test No. 1 (ceiling, walls and floor dark) of the difference between—

	per cent.	
Test No. 2 (ceiling light, walls and floor dark) and Test No. 1 (ceiling, walls and floor dark)	= 79	$= N_1$
Test No. 3 (ceiling and walls light, floor dark) and Test No. 5 (walls light, ceiling and floor dark)	= 132	$= N_1 + N_4$
Test No. 8 (ceiling and floor light, walls dark) and Test No. 7 (floor light, ceiling and walls dark)	= 84	$= N_1 + N_5$
Test No. 4 (ceiling, walls and floor light) and Test No. 6 (walls and floor light, ceiling dark)	= 179	$= N_1 + N_4 + N_5 + N_7$
Test No. 5 (walls light, ceiling and floor dark) and Test No. 1 (ceiling, walls and floor dark)	= 63	$= N_2$
Test No. 3 (ceiling and walls light, floor dark) and Test No. 2 (ceiling light, walls and floor dark)	= 115	$= N_2 + N_4$
Test No. 6 (walls and floor light, ceiling dark) and Test No. 7 (floor light, ceiling and walls dark)	= 68	$= N_2 + N_6$
Test No. 4 (ceiling, walls and floor light) and Test No. 8 (ceiling and floor light, walls dark)	= 163	$= N_2 + N_4 + N_6 + N_7$
Test No. 7 (floor light, ceiling and walls dark) and Test No. 1 (ceiling, walls and floor dark)	= 11	$= N_3$
Test No. 6 (walls and floor light, ceiling dark) and Test No. 5 (walls light, ceiling and floor dark)	= 16	$= N_3 + N_6$
Test No. 8 (ceiling and floor light, walls dark) and Test No. 2 (ceiling light, walls and floor dark)	= 16	$= N_3 + N_5$
Test No. 4 (ceiling, walls and floor light) and Test No. 3 (ceiling and walls light, floor dark)	= 63	$= N_3 + N_5 + N_6 + N_7$

From these equations the values of N are found to be as follows:—

$N_1 = 79$ per cent.	$N_4 = 53$ per cent.
$N_2 = 63$ " "	$N_5 = 5$ " "
$N_3 = 11$ " "	$N_6 = 5$ " "
$N_7 = 42$ per cent.	

The sum of all the N values obtained separately is 258%, which agrees with the value of the increase of test No 4 over test No. 1. The values are interdependent, however. For each of the other three sets of eight tests the seven values of N were obtained in the same way. These values are shown below.

	Light Source.			
	1 bare lamp per cent.	1 lamp with reflector per cent.	3 bare lamps per cent.	3 lamps with reflector per cent.
N_1	79	33	96	29
N_2	63	19	77	26
N_3	11	5	4	—1
N_4	53	23	54	37
N_5	5	0	6	4
N_6	5	12	11	10
N_7	42	58	60	45
Total	258	150	308	150

The negative value of N_3 is of course impossible and shows the presence of a slight error. Of the seven parts into which the increase in illumination by reflection is divided, four are seen to be of considerable value while the three others have little effect. The four which are important are:—

N_1 = Increase due to ceiling alone.
N_2 = " " " walls "
N_4 = " " " interaction of ceiling and walls
N_7 = " " " " " " , walls and floor

The floor is therefore of little value as a secondary source of light except in the one case where the ceiling and walls are also light in color.

The effect of the interaction of ceiling and floor (N_5) is small due to the double reflection of each ray causing the coefficient or reflection (K) to enter in as the second power or higher. However, although K enters in at least as the third power in producing the interaction of ceiling, walls and floor (N_7), the fact that the total flux of the light source aids in making up this value causes it to be of considerable importance.

As would be expected, the ceiling and walls have a much greater effect with bare lamps than with reflectors. The walls have a greater effect with three lamps than with one lamp, and this is true of the ceiling when bare lamps are used.

Comparing the ceiling and walls, it is seen that the ceiling has the greater reflecting value. The increase of the reflection from the ceiling over the reflection from the walls is from 12% to 25%, except in the case where one lamp is used with a reflector. Here the ceiling has 74% more effect than the walls, because the reflector is so placed that a large part of the total flux is thrown directly on the plane of illumination and does not strike the walls. This arrangement corresponds closely to the

case of a large room and shows the importance of a light ceiling in stores, auditoriums, etc.

It is interesting to note the effect in the case which would be most commonly met with in practice, namely three lamps with reflectors. Light ceiling alone increases the illumination by 29%; light walls alone by 26%; light floor alone practically 0%; light ceiling and walls together by 37% plus their separate effects, or a total of 92%, and light ceiling, walls and floor 150%.

ANALYSIS OF THE EFFECT OF REFLECTION ON UNIFORMITY OF ILLUMINATION.

The uniformity of illumination may be affected by reflected light in three ways:—

1—An illumination of the same value at all points may be added to the direct illumination, thus increasing the uniformity.

2—The higher values produced by direct illumination may be increased by reflection less than the lower values, thereby increasing the uniformity.

3—The higher values produced by direct illumination may be increased by reflection more than the lower values, thereby decreasing the uniformity.

In order to analyze the effect in detail, the values of N_1, N_2—N_7 have been found and are shown below. It should be noted that the light units were not placed in any test with the idea of obtaining uniform illumination.

As many of these values are obtained from the third significant figure in the illumination reading, their accuracy is correspondingly reduced. All negative values are of course impossible.

TESTS NOS. 1-8.

One clear, bare 40-watt tungsten lamp on ceiling.

Station	Foot-Candles Test No. 1 All dark	Foot-Candles Increase N_1	N_2	N_3	N_4	N_5	N_6	N_7	ΣN
1	.09	.03	.12	.00	.11	.01	.04	.04	.35
2	.10	.04	.13	.01	.09	.02	.01	.04	.34
3	.14	.08	.12	.00	.09	.03	.02	.08	.42
4	.17	.07	.12	.01	.13	.03	.00	.02	.38
5	.22	.15	.13	.03	.09	.00	—.03	.19	.56
6	.30	.21	.05	.02	.12	—.01	.03	.11	.53
7	.26	.24	.15	.03	.07	—.04	—.02	.21	.64
8	.26	.37	.16	.02	.04	.00	.01	.05	.65
9	.17	.08	.09	.00	.14	.05	.02	.04	.42
10	.18	.46	.16	.04	.09	—.04	—.06	.18	.83
Mean (Stations 1-8)	.19	.15	.12	.02	.10	.00	.01	.08	.48
Maximum variation from mean		206% (Station No. 10)	—58% (Station No. 6)	100% (Station No. 10)	40% (Station No. 9)			138% (Station No. 5)	

It has been previously shown that the floor alone, the interaction of the floor and walls and the interaction of the floor and ceiling have only a slight effect on the intensity. They, therefore, do not greatly affect the uniformity.

The ceiling alone, as would be expected, adds an illumination (N_1) very high in the center of the room and falling off to a very low value at the sides. The intensity is so great at the center that even though the illumination at this point is below the average when the ceiling is dark, it becomes the highest point and the point of maximum variation when the ceiling is light. The variation from the mean becomes 88% at this station, while it was 58% before at the point of maximum variation, which was station No. 6. This result shows that the reflecting value of the ceiling is greatest directly under the light source, a consideration which should receive especial attention in designing the lighting system for a room in which the ceiling is light in the center, shading out to a darker color at the sides. If the room is lighted by a central light unit the calculated illumination should be made considerably higher at the sides, if uniform illumination is desired.

The walls add a fairly uniform illumination (N_2) which is highest near the light source. The walls decrease the maximum variation from 58% to 36%.

The interaction of the walls and the ceiling together adds a fairly uniform illumination (N_4). The great variation pro-

TEST NOS. 9-16.

One 40-watt frosted tip tungsten lamp with reflector, place close to ceiling.

Station	Foot-Candles Test No. 9 All dark	Foot-Candles Increase N_1	N_2	N_3	N_4	N_5	N_6	N_7	ΣN
1	.08	.05	.07	.01	.06	.00	.05	.15	.39
2	.09	.05	.07	.01	.06	.01	.05	.13	.38
3	.15	.09	.10	.03	.03	—.02	.00	.17	.40
4	.25	.11	.03	.00	.08	—.05	.04	.18	.39
5	.36	.11	.08	.02	.10	—.01	.01	.26	.57
6	.58	.16	.06	—.03	.07	.05	.04	.37	.72
7	.53	.17	.12	.05	.12	.00	.01	.30	.77
8	.87	.21	.02	—.05	.11	.04	.18	.19	.70
9	.22	.06	.06	.00	.08	.01	.03	.19	.43
10	.82	.26	.01	—.05	.12	.04	.15	.27	.80
Mean (Stations 1-8)	.36	.12	.07	.005	.08	.00	.05	.22	.54
Maximum variation from mean		117% (Station 10)	—86% (Station 10)		—63% (Station 3)		385% (Station 8)	68% (Station 7)	

duced by the ceiling alone is more than cancelled by the increased uniformity produced by the walls (N_2) and the interaction of the walls and ceiling (N_4). With walls and ceiling light, the maximum variation is 48% as compared with 58% when all are dark, and 88% when the ceiling alone is light.

As in the previous case the floor does not greatly affect the intensity and consequently the uniformity. The general effect is to increase the uniformity by adding a fairly even illumination. The ceiling again adds a non-uniform illumination (N_1) high in the center and low at the sides. This serves to increase the uniformity slightly, however. The walls add an illumination (N_2) high at the sides and low near the center thereby increasing the uniformity.

The additional effect on the uniformity caused by the interaction of the walls and ceiling is not great; but since the walls and ceiling each alone increases the uniformity, they effect quite a considerable increase when used together. The maximum variation from the mean is reduced from 142% to 92%. When the effect of the floor is added to this, the maximum variation is reduced to 80%.

TESTS NOS. 17-24.

Three clear, bare 40-watt tungsten lamps on ceiling.

Station	Foot-Candles Test No. 17 All dark	Foot-Candles Increase N_1	N_2	N_3	N_4	N_5	N_6	N_7	ΣN
1	.37	.31	.40	.02	.22	—.01	.05	.34	1.33
2	.41	.44	.41	.03	.21	.04	.03	.45	1.61
3	.40	.37	.41	.02	.26	.07	.10	.19	1.42
4	.48	.59	.36	.02	.32	.08	.06	.14	1.57
5	.49	.40	.38	.01	.29	.05	.07	.26	1.46
6	.62	.53	.34	.02	.26	.08	.01	.27	1.51
7	.51	.38	.35	.01	.31	.02	.04	.27	1.38
8	.54	.65	.33	.04	.22	—.03	.04	.32	1.57
9	.39	.58	.36	.02	.29	.07	.04	.36	1.72
10	.44	.70	.34	.02	.25	—.01	.04	.27	1.61
Mean (Stations 1-8)	.48	.46	.37	.02	.26	.04	.05	.28	1.48
Maximum variation from mean		.52% (Station 10)	—11% (Station 8)	100% (Station 8)	23% (Station 4)		100% (Station 3)	61% (Station 2)	

As in the one-lamp tests, the floor has very little effect. The ceiling adds an illumination high in the center and low at the sides. The uniformity is slightly improved. The walls add

an illumination practically uniform, the maximum variation in the added illumination being only 11%. The high points are near the walls.

The combined effect of the ceiling and walls is to add an illumination nearly uniform and thereby decrease the maximum variation from 29% to 17%. The combined effect of the ceiling and floor is to raise the low points in the illumination added by the ceiling alone. This has a very good effect on the uniformity by reducing the maximum variation from 29% to 9%.

TESTS NOS. 25-32.

Three 40-watt, frosted tip tungsten lamps with reflectors; units placed close to ceiling.

Station	Foot-Candles Test No. 25 All dark	Foot-Candles Increase N_1	N_2	N_3	N_4	N_5	N_6	N_7	ΣN
1	.53	.17	.29	.01	.34	.10	.09	.07	1.07
2	.89	.25	.33	.08	.38	—.03	.02	.40	1.43
3	.72	.20	.26	—.03	.33	—.01	.11	.41	1.27
4	1.14	.37	.26	.02	.25	—.15	.02	.60	1.37
5	.72	.27	.27	.02	.35	—.02	.06	.35	1.30
6	1.31	.35	.11	—.15	.29	.11	.19	.60	1.50
7	.77	.14	.22	.00	.45	.17	.10	.43	1.51
8	1.20	.36	.13	—.09	.29	.13	.23	.35	1.40
9	1.10	.36	.26	—.01	.28	.06	.09	.35	1.39
10	1.05	.38	.37	—.07	.07	.09	.09	.55	1.48
Mean (Stations 1-8)	.91	.26	.23		.33	.04	.10	.40	1.36
Maximum variation from mean		46% (Station 7 and 10)	61% (Station 10)		—55% (Station 10)		130% (Station 8)	—93% (Station 1)	

The floor has little effect, though the tendency is to increase the uniformity. The ceiling adds an illumination higher near the center than at the sides. The effect is to make the total illumination slightly more uniform. The walls add an illumination higher at the sides than at nearby points, but highest directly in the center. The reflection from the walls reduces the maximum variation from 44% to 29%.

The interaction of the walls and ceiling adds an illumination high at the sides and low near the center, thereby increasing the uniformity. This combination and the combination of walls and floor have about the same effect, reducing the maximum variation from 44% to 26% and 25% respectively. These two combinations do more toward securing uniform illumination than any other in these eight tests.

DETERMINATION OF THE ANGLE BELOW WHICH LUMENS GENERATED ARE LUMENS EFFECTIVE.

In his presidential address before the Illuminating Engineering Society Convention in 1907, Dr. Clayton H. Sharp defined the lumen as the unit of flux or quantity of light, and suggested a method of employing this unit in illumination calculations. This method has been used more or less by engineers during the past year, but for the benefit of those not familiar with flux calculations, a brief review of the method is given below.

The connection between lumens and foot-candles can be shown very simply. A foot-candle is defined as the intensity of illumination due to unit source of light placed one foot distant from the plane on which the light falls. A lumen is defined as the flux of light due to unit source of light emitted through unit solid angle. Since there are 4π solid angles in a sphere and also 4π square feet of superficial area in a sphere 1 ft. in radius there is one lumen per square foot and therefore one lumen will give one foot-candle intensity over an area of one square foot on a surface one foot away from the unit source of light. It immediately follows that if the total flux of light in lumens is divided by the square feet on which the lumens fall, the average foot-candle intensity is obtained. Knowing the area of a room it becomes only necessary to find the effective flux of light, when the average foot-candle intensity can be determined quickly. The effective flux will depend upon the shape of the photometric curve and the amount of light reflected from the ceiling and the walls.

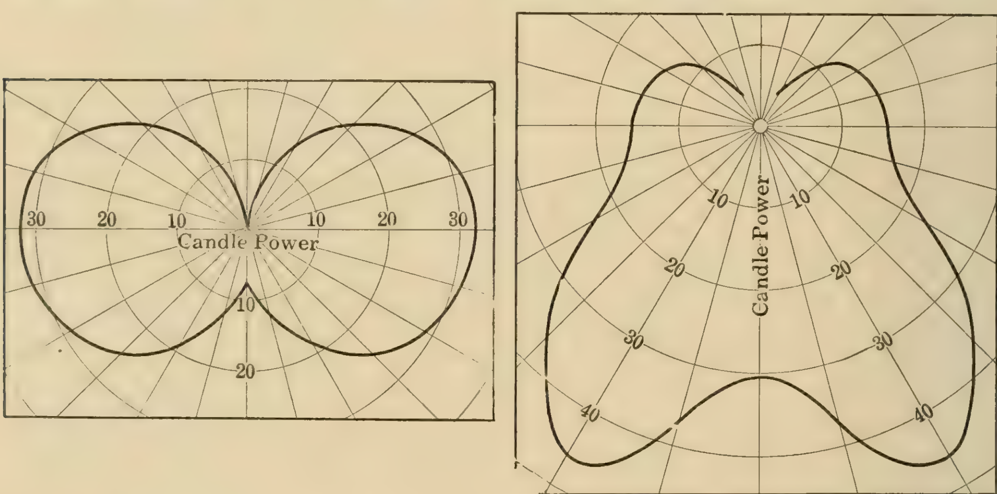
The most convenient way of applying the flux method of calculation is to determine from the photometric curve the mean candle-power up to the angle below which the lumens generated are effective. This mean value of candle-power is then multiplied by a constant which is the number of solid angles below the angle selected, and the product is the effective lumens.

For example, suppose that using the equipment giving the polar candle-power curve shown in Fig. 3, it is decided that the lumens below 75 degrees are effective under certain conditions, of, say, light ceiling and walls in a room 15 ft.x20 ft. The mean candle-power up to 75 degrees is 34.2; the number of solid

angles up to 75 degrees is 4.65. Therefore the effective lumens are 34.2×4.65 or 159.0. Dividing this figure by the area, 300 square feet, the average intensity is obtained as .53 foot-candles.

Due to the variety of conditions encountered in illumination problems, it is frequently a difficult matter to determine the effective angle. For this reason calculations have been made for showing the effective angle under each of the conditions under which the illumination tests were made. These calculations will prove of convenience for reference by those using the flux method of calculation.

In determining the angle the following method was used. For each of the one-lamp test units a curve was plotted showing at each angle up to 90 degrees the lumens generated below that



Figs. 2 and 3.—Distribution of Light About a 32-c.p. Tungsten Lamp, Clear, Bare and Frosted Tip with Reflector.

angle. From this curve the angles for lumens effective under various conditions were obtained. The curve is shown in Fig. 4.

For the three-lamp tests the photometric curve used was one for which each candle-power value was the sum of the corresponding values of the three curves of the units used in the test.

In the *Electrical World*, July 11th, 1908, J. R. Cravath and V. R. Lansingh proposed the following formula for determining the total watts necessary for the illumination of a room with a certain desired foot-candle intensity:

Total watts=area of room×foot-candles×watts per lumen.

The quantity, watts per lumen, is the number of watts necessary to produce 1 foot-candle over an area of 1 square foot. In the article mentioned a number of determinations of watts per lumen from actual illumination tests under various conditions were given. This formula will be of considerable value when a sufficient number of such determinations have been published. The authors have, therefore, determined the value of

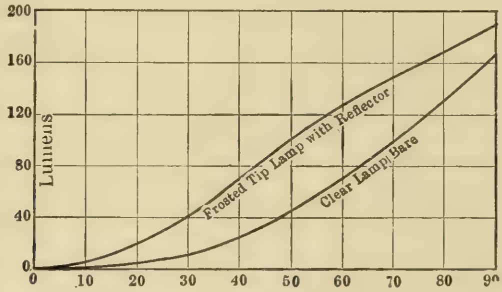


Fig. 4.—Curves Showing Effective Lumens with 40-watt Tungsten lamp with and without Reflector.

watts per lumen under each of the conditions of these reflection tests. The rated wattage of the lamps was used, the values found being shown in the table below.

Test No.	Conditions	Mean foot candles	Lumens Effective	Effective angle-degrees	Watts per lumen
	One bare lamp				
	Calculated illumination	.16	44	50	.91
1	Ceiling, walls and floor dark	.19	52	53	.77
2	Ceiling light, walls and floor dark	.34	94	69	.43
3	Ceiling and walls light, floor dark	.56	154	86	.26
4	Ceiling, walls and floor light	.68	187	(over 90)	.21
5	Walls light, ceiling and floor dark	.31	85	66	.47
6	Walls and floor light, ceiling dark	.34	94	69	.43
7	Floor light, ceiling and walls dark	.21	58	56	.69
8	Ceiling and floor light, walls dark	.37	102	71	.39
	One lamp with reflector				
	Calculated illumination	.36	99	50	.40
9	Ceiling, walls and floor dark	.36	99	50	.40
10	Ceiling light, walls and floor dark	.48	132	63	.30
11	Ceiling and walls light, floor dark	.63	173	82	.23
12	Ceiling, walls and floor light	.90	248	(over 90)	.16
13	Walls light, ceiling and floor dark	.43	118	58	.34
14	Walls and floor light, ceiling dark	.49	135	64	.30
15	Floor light, ceiling and walls dark	.37	102	51	.40
16	Ceiling and floor light, walls dark	.49	135	64	.30

Test No.	Conditions	Mean foot candles	Lumens Effective	Effective angle-degrees	Watts per lumen
	Three lamps bare				
	Calculated illumination	.41	113	47	1.06
17	Ceiling, walls and floor dark	.48	132	50	.91
18	Ceiling light, walls and floor dark	.94	258	66	.47
19	Ceiling and walls light, floor dark	1.57	432	83	.28
20	Ceiling, walls and floor light	1.96	540	(over 90)	.22
21	Walls light, ceiling and floor dark	.85	234	63	.51
22	Walls and floor light, ceiling dark	.92	253	65	.47
23	Floor light, ceiling and walls dark	.50	137	50	.88
24	Ceiling and floor light, walls dark	.99	272	67	.44
	Three lamps with reflectors				
	Calculated illumination	.89	245	45	.49
25	Ceiling, walls and floor dark	.91	250	46	.48
26	Ceiling light, walls and floor dark	1.17	322	56	.37
27	Ceiling and walls light, floor dark	1.74	479	80	.25
28	Ceiling, walls and floor light	2.27	625	(over 90)	.19
29	Walls light, ceiling and floor dark	1.15	316	55	.38
30	Walls and floor light, ceiling dark	1.23	338	57	.36
31	Floor light, ceiling and walls dark	.90	248	46	.48
32	Ceiling and floor light, walls dark	1.20	330	56	.36

In the above table, an interesting point is the fact that when reflectors are used, the mean foot-candles and consequently the watts per lumen are almost exactly the same in the calculated illumination and under the conditions of dark ceiling, walls and floor. When no reflectors are used, these values differ considerably.

It was shown above that the floor has little value as a reflector; therefore the figures in which the floor is involved will not often be used. Comparing the values with one lamp and reflector with those with three lamps and reflectors, the effective angle with light ceiling and dark walls and floor is 63 degrees in the first case and 56 degrees in the second case. The average angle of 60 degrees may therefore be considered as good for the assumed conditions with small rooms. The condition of light ceiling and walls and dark floor may be considered as correspondingly more or less closely to a large room, since the reflection from the walls would be approximately equal to the light furnished from distant light sources. The angle of 80 degrees as shown in the table, may therefore be used for both large and small rooms. It is interesting to note that Cravath

and Lansingh selected from tests in large rooms the angle 75 degrees for these conditions.

The effective angle, when reflectors are used, is from 45 to 50 degrees with small rooms. This figure would be increased for large rooms, owing to the effect of distant lamps.

The value of watts per lumen with tungsten lamps when the ceiling alone is light and reflectors are used may be considered approximately .35 for small rooms. When the ceiling and walls are both light, the table shows .25. This is exactly the figure which Cravath and Lansingh determined for large rooms with light ceiling and dark walls, using prismatic reflectors and tungsten lamps.

* * * * * *

So far as the authors are aware, these are the first experiments of this nature to be published. For that reason, they may excite some criticism as to the method of carrying them out and the results deduced. It is hoped, however, that they will at least form the basis of further experiments of a similar nature.

The authors desire to express their appreciation of the valuable assistance rendered by Messrs. W. J. Cady, A. J. Marshall, E. B. Rowe, C. W. Heck and H. M. Lauritzen, during the tests and in the preparation of the paper.

DISCUSSION.

Dr. A. S. McAllister:—The paper contains one surprising result, namely, that the illumination of a room having light-colored walls and ceiling is better when a lamp is used without a reflector than when equipped with a reflector. Test No. 3 shows that when no reflector is used the minimum illumination is 0.35 foot-candle and the variation is 48 per cent. Test No 11 indicates that when a reflector is placed on the lamp the minimum illumination is reduced to 0.26 foot-candle, and the variation is increased to 92 per cent. Since for many purposes the proper criterion is the highest minimum with the least variation of illumination, it would seem that the use of a reflector is disadvantageous. However, there are conditions under which this conclusion would not be applicable, such as in the lighting of offices, libraries or dining rooms where non-uniformity of illumination is desirable.

Mr. P. S. Millar:—Given a point source radiating equally in

all directions; given further a location for that source in the center of a sphere having a uniform coefficient of reflection throughout the entire interior surface:—then

$$e = 1 \frac{1}{1 - K},$$

e being the cumulative illumination and K being the coefficient of reflection of the sphere surface.

Certain illuminating engineers and writers on the subject have endeavored to apply this formula to a compution of the effect of reflected light from ceilings and walls in increasing the intensity of illumination on a given plane in a room. This cannot be done, however, for with a variation from a uniformly radiating source, from a perfect sphere, and from a uniform coefficient of reflection, the formula no longer applies. In 1906, the speaker showed that K varies largely with the location of the lamps in the room. All of these variables have come to be recognized, and we have reached the point where we know that the formula is useless for practical purposes in illuminating engineering.

This paper represents the first step in the collection of suitable data bearing on the important subject of ceiling and wall reflection. Experimental research of the character which the authors have undertaken is what this society needs. It will go far toward putting illuminating engineering on a sure foundation and a permanent basis. It seems to me that the society is indebted to the authors for pioneer work along this line and that it is to be hoped that they will continue their research in the near future.

Mr. V. R. Lansingh:—The room in which these tests were made was comparatively small, about 24 feet long by 15 feet wide. It is interesting to note the effect of the low walls and ceilings in such a small room, as compared with the effect of distant lamps in a large room such as a department store. In the actual test made here, it was found that the angle below which the lumens generated are lumens effective is between 75 and 80 degrees with light walls. In the case of department stores and similar installations, where there is the effect of distant lamps the tests given in the paper by Mr. Cravath and myself show also the angle of 75 degrees. In other words, these tests show that the effect of light walls in small rooms, is about equivalent to distant lamps in large rooms.

Mr. Alfred A. Wohlauer:—I agree with Mr. Millar as to the importance of this paper, and I also appreciate its value; at the same time I wish to acknowledge that Mr. Millar has given information concerning the utilization of the theory of the integrating sphere for the pre-calculation of the illumination due to the reflection from walls and ceiling.

Mr. T. W. Rolph:—As to the point Dr. McAllister brought up, it should be noted that in these tests neither with the bare lamps nor with the reflectors was there any attempt to place units so as to obtain uniform illumination; therefore, the tests do not show the effect of reflectors upon the uniformity of illumination, but only the effect of reflection from the walls, ceiling and floor.

TRANSACTIONS OF THE

Illuminating Engineering Society

VOL. III. NOVEMBER, 1908. NO. 8.

At a meeting of the Council of the Society held on Friday, November 13, the Treasurer submitted a report showing a balance at the end of October of $3284.44, and stated that he had recently received a report from the Treasurer of the Convention Committee, giving an account of the receipts and disbursements at the Philadelphia Convention and forwarding therewith the unexpended balance of $245.33. The report was approved and motion was unanimously passed to extend a vote of thanks to the Convention Committee for their very successful carrying-out of the recent Convention. Unpaid bills amounting to $729.40 were reported by the Finance Committee and were approved by the Council for payment.

The Chairman of the Committee on Certificates of Membership stated that the certificates had been printed and that a seal for the Society had been secured. The report of the committee was approved.

A petition to amend the Constitution, duly signed by more than twenty-five members, was presented for the consideration of the Council. The proposal was unanimously approved, and the Secretary was authorized to send out a letter-ballot on its adoption.

The Secretary reported the names of four members who were elected to membership over two months ago, and who have failed to reply to three notices of dues payable which were addressed to them. By action of the Council, these memberships were cancelled.

The names of eighteen applicants for membership were presented, having been approved by the respective examining boards. It was unanimously moved and carried that these applicants be elected.

MEMBERS ELECTED NOVEMBER 13, 1908.

BALL, F. L., Appliance Manager, Malden Electric Company, Malden, Mass.

BENSON, FRED T., Manager, Lamp Department, General Electric Company, Chicago, Ill.

CARTWRIGHT, J. W., Treasurer, Bangor Street Railway and Electric Company, Bangor, Maine.

FOSTER, JOHN W., Holophane Company, 227 Fulton St., New York.

FRARIN, W. A., Salesman, 121 North 13th St., Philadelphia, Pa.

GROTZ, R. B., Holophane Company, 227 Fulton St., New York.

HORNING, GEORGE R., Superintendent, Northern Liberties Gas Company, 50 Laurel St., Philadelphia, Pa.

MACDONALD, NORMAN D., Electrical Testing Laboratories, 80th St. and East End Avenue, New York.

PIERCE, R. F., Manager, Minerallac Company, 839 Monadnock Building, Chicago, Ill.

PLACE, G. G., Chicago Representative of "Illuminating Engineer," 430 West Adams St., Chicago, Ill.

ROBERTS, O. M., Electrical Contractor and Engineer, Athens Engineering Company, Athens, Ga.

ROWLAND, ARTHUR J., Professor of Electrical Engineering, Drexel Institute, 32nd and Chestnut Sts., Philadelphia, Pa.

SAWIN, GEORGE A., Public Service Corporation of New Jersey, Newark, N. J.

SCHWERIN, B. G., Commercial Engineer, 424 Walnut St., Philadelphia, Pa.

SCRIBNER, EDWARD E., Manager, Metal Reflector Dept., Holophane Company, 227 Fulton St., New York.

SPENCER, ARTHUR R., Photometrist, Bryn Mawr, Pa.

TEEGARDEN, L. W., Tungsten Lamp Dept., General Electric Company, Park Building, Pittsburg, Pa.

YOST, VICTOR A., Electrical Contractor, Ossining, N. Y,

CHICAGO SECTION.

A meeting of the Section was held on November 12, 22 members being present. The meeting was devoted to discussions of the following three Convention papers which were abstracted by Mr. A. Scheible and Mr. J. R. Cravath:

"The Intensity of Natural Illumination Throughout the Day," by Mr. Leonard J. Lewinson; "Some Experiments on Reflections from Ceilings, Walls and Floors," by Messrs. V. R. Lansingh and T. W. Rolph; and "The Calculation of Illumination by the Flux-of-Light Method," by Messrs. J. R. Cravath and V. R. Lansingh.

NEW YORK SECTION.

The regular monthly meeting of the Section was held at the Carnegie Library, St. Gabriels Branch, East Thirty-Second Street, on Thursday evening, November 12. Mr. L. B. Marks outlined some of the requirements in library lighting and some considerations which he had in mind in designing the lighting of the library. Those in attendance then visited the various rooms of the library, examining the lighting arrangements and the effects produced. Later there was an informal discussion of the lighting of the library, which discussion was participated in by a number of the members of the Society. Representatives of the library staff were present in considerable numbers. About thirty-five members of the Society were present.

PHILADELPHIA SECTION.

At a meeting of the Section held on November 20, the following papers were read and discussed:

"Lighting in the Roger Williams Building, Seventeenth and Chestnut Streets," by Arthur J. Rowland, Professor of Electrical Engineering, Drexel Institute; "Lighting in the Office Building of the Philadelphia Electric Company, 1000 Chestnut Street," by Mr. P. H. Bartlett, Supt. Installation.

The members were afforded an opportunity to view the lighting equipments described.

STRUCTURAL DIFFICULTIES IN INSTALLATION WORK.[1]

BY JAMES R. STRONG.

The subject assigned me is one seldom discussed; not because there are no structural difficulties in the installation of electrical wires for illuminating purposes, but because such difficulties do not usually arise for a considerable period after the installation has been put in use and these difficulties are then taken as a necessary accompaniment of the rigid type of present day equipments.

It may not be a generally accepted fact but it is nevertheless true, that the best electrical installation, from the point of view of the first-class contractor who intends to remain in business, is that installation which requires the least amount of changing and alteration after completion. Such an installation demands as a prerequisite a full knowledge as to exactly what is wanted as well as a complete scheme that will give the maximum desired results with a minimum maintaining charge.

In commercial buildings the interest on the installing cost is, of course, a factor to be considered; but this factor becomes very small in structures not strictly used for money making purposes —as for example private residences.

Modern electric lighting installations in the better class of buildings are of some form of concealed conduit work, with iron or steel outlet boxes at the fixture locations. Therefore, the electrical equipment is as much a part of the structure of the building as is the plumbing or heating equipment, and any additions or alterations in the conduit work after the completion of the building must to some degree cause weakness in walls, floors or plaster;to avoid changes in such electrical installations it is obviously necessary so to locate the outlets at the beginning of the work that all desired results may be obtained by the use of economical, artistic and harmonious lighting fixtures.

The above requirements when first considered seem very sim-

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

ple and easy of fulfillment, and indeed they would form a simple proposition were all the conditions fixed; but, when on second thought one considers that every installation must, or should, be so designed as to allow a maximum amount of changes without affecting the efficiency of the results, the problem becomes more complex and worthy of the attention of all those who wish the lighting industry to make progress.

Take for example the floor of a typical office building and consider what it means to lay out the lighting system so that each new tenant with his special requirements, his different arrangment of high and low partitions, and his different style of furniture—may still have enough light of ample intensity and diffusion and at suitable locations.

It is not sufficient to dismiss the difficulty by saying that each new tenant should do his own shifting of outlets, for this is apt to mean a deterioration of the installation as a whole. It must also be borne in mind that in many cases it is quite impracticable to shift concealed conduit outlets as, for example, in a ceiling where the iron girders are not more than one inch above the finished plaster line and the floor above occupied by other tenants. The necessary shifting, of course, could easily be done by the use of mouldings on the ceiling or walls, but this method at once cheapens the character of the work; not only are the mouldings not so safe or clean as conduit but in moulding work it is very easy for irresponsible parties to cut in to the work and make more or less dangerous attachments. It must also be borne in mind that if the outlets as already installed meet the demands of the prospective tenant the space may more easily be rented to advantage.

It would seem, therefore, that in designing the lighting for an office building the proper method of procedure is not the one frequently followed of arranging the circuits in each separate office irrespective of any consideration of adjacent rooms. Such a method is to be avoided even though the space has been leased before the plans have reached the hands of the illuminating engineer. The better method is to consider each floor as a whole, bearing in mind the class of tenants who would be likely to occupy an office building in a given locality.

Office buildings are generally arranged with the main or

high partitions midway between windows; a certain minimum size is selected for an office space, and the larger offices are multiples of such a minimum space. If, therefore, the outlets for general illumination are placed on the center line of windows, and if other outlets are placed around the ceiling a short distance inside the lines of partitions it would seem as if every possible requirement could be met by simple fixtures, and the outlets not needed be capped up. This plan would probably involve a greater number of outlets in the original layout than absolutely necessary; but when it is considered that no changes would probably be required it will be appreciated that the additional first cost would be more than made up in saving in the maintenance cost of the first few years. Moreover, the installation as a whole would manifestly be a better one, owing to such freedom from changes and alterations, and already pointed out, the offices would be more rentable.

The above general statements will also apply to any residence, in which class of work there seems to be a growing tendency to limit the number and capacity of outlets to the bare requirements of a scheme of decoration and furniture layout that has been decided on by the original owner, architect or decorator with no regard as to possible new requirements of a future purchaser or even changes desired by the original owner after he has become tired of a given color scheme or arrangement of interior.

Consider for example any room in a private residence where the original color scheme was light and the engineer depended upon a large co-efficient of reflection for walls and ceiling. Because of close competition the outlets were installed and the wires proportioned to just cover the above requirements. In a year or so the owner wishes the color changed to a dark tint and there will be little or no reflection from the walls or ceiling. Then it becomes necessary either to exceed the requirements of the Insurance Code or to do additional wiring with the attending cutting and patching and the possible weakening of studs or floor timbers.

If the outlets were installed in number and capacity sufficient for the darkest probable treatment very little would be added to the first expense; and the decrease of the light to the exact amount required would then be done in the fixture and lamp.

Not only should the initial equipment be such as to cover any probable condition, but the outlets themselves should be so located that any re-arrangement of furniture is easy and practical. In a bedroom, for example, it has often been the practice to locate a ceiling outlet near the wall, or a side wall outlet near the ceiling, to provide for a dressing table fixture to light the face and hair. When subsequently the spirit of unrest takes possession of the occupant of the room and she wishes to change the position of the dressing table and the bureau, it is a difficult matter to re-arrange the fixtures.

If, in place of the above special dressing table fixture, four side-wall outlets had been placed at the most probable locations of dressing table and bureau, then the articles of furniture could be interchanged at will, with very slight changes in the fixtures, and perhaps no change whatever except in the glass-ware. This plan would render the room not only more attractive to its occupant but would also assist in selling the residence to a prospective purchaser. It should be (and is) quite possible for the illuminating designer so to design a fixture and glass-ware that a side bracket on simple and attractive lines will accomplish for a dressing table all the results that are now claimed for the special dressing table fixture mentioned above, which special fixture is often recommended by some of the fixture companies.

Illustrations like the above could easily be multiplied, but it is believed that enough has been said to indicate the need of more attention to the elasticity of any proposed layout of conduit and wires for illuminating work, so that changes in the requirements for light will involve little or no changes in that portion of the equipment which forms a part of the construction of the building.

It is, of course, quite proper that the illuminating engineer should give his best skill to the design and arrangement of fixtures, glass-ware and lamps at existing outlets so that the best possible results may be obtained in any installation which comes under his charge; and great credit is due our illuminating engineers for the advance made in this art during the last few years.

It is also true that in any installation where the layout of the outlets is under the engineer's charge, he must bear in

mind that he is dealing not only with the science of illumination, but also with the vagaries of human nature. The love of change which seems inherent in the "Genus Homo" is as much a part of the equation as is the "flux of light."

The discussion of this—probably the most important—branch of the subject seems to have prolonged this paper unduly, and it is necessary for me to confine myself to the mere mention of certain other "structural difficulties." I do not wish to appear to criticise the valuable work being done by the electrical engineering profession here represented, but I feel that the mention of certain items which appear as "structural difficulties" from the contractors standpoint may be a benefit to the profession as a whole. I refer particularly to the "specification" now written, to a large extent, by the consulting engineer and used by the contractor as a basis for his estimates. It is most desirable that this "specification" be made as simple and concise as possible, and that specialties should be avoided, such as the special stranding of wire different from the standard; extra heavy carrying capacity for switchboards and panel boards; extra spacing between conductors of different polarities; special outlet boxes different from the standard; the specifying of a particular appliance when several of equal excellence are on the market; the unfair clause requiring the contractor "to make any alteration of outlets requested without additional charge" and various other items along the same line. It is for the benefit of all concerned that electrical work be as near the standard as possible, and it will probably be conceded that the standards established by the Underwriters are sufficient to ensure safe and good construction. Standardization means economy and will unquestionably tend to minimize the cost of construction, and it must be admitted that the lower the cost of construction the more likelihood of the extension of the electrical field which must prove of benefit to all interested.

DISCUSSION.

Mr. H. Calvert:—With Mr. Strong's paper I am inclined partly to agree and partly to disagree. There is no question but that the character of the work with which he is dealing, that is to say, wiring in concealed conduits, is such that it is a

very difficult matter to make any changes, but it seems to me that his suggestion of putting in additional outlets in office buildings to suit all possible conditions of arrangement of the office, and locations of partitions, is increasing the cost of the first installation beyond all justification. I presume in the majority of cases the original partitions are not changed, but if they are changed, it is possible that the partitions will be placed in new locations which will not suit the outlets, no matter how many of them there may be.

The best way that I can see of solving the problem is by the installation of receptacles in the baseboard around the room, and using them for desk lamps for local illumination, depending largely on the general illumination of the room for other purposes.

With regard to the wiring of houses, residences in particular, it generally happens that the design of the room with reference to the location of the doors and the windows will permit, at least in the average house, of only one location of the different articles of furniture. For instance, as a rule a bed or bureau can be located in only one place, consequently, although the good lady of the house generally does desire to make a change, she is limited not so much by the location of the outlets and fixtures as by the architectural design of the room.

To install a great number of outlets either in a residence or in an office building increases the cost of them beyond all justification, because if the houses or offices are to be rented, or bought, as a rule it is not the location of the outlets that determine the price; it is the general location of the building and the surroundings, and other conditions, the wiring being of a secondary consideration.

Mr. Walton Forstall:—I may add a little to what Mr. Calvert said as to the effect upon first cost of placing outlets wherever it is thought they will be needed in the future. Gas companies have tried to insure the use of piping amply large for all future demands, and have thought the only safe rule to follow was to consider that all outlets provided would be used simultaneously. This rule has undoubtedly caused in some cases the use of larger piping than was necessary, and its operation would heavily penal-

ize any installation of alternative outlets. If there is a disposition on the part of architects or owners to provide such outlets, then the house piping rules must be modified so that in such cases the size of piping will be determined not by total number of outlets, but by the probable number to be used simultaneously.

In the United Gas Improvement Company's building in Philadelphia, the piping system was planned so as to include all possible outlets, and using any combination desired. If my memory is correct, the outlets were laid out along the centre line of each window, extending back from the face of the outside wall to the interior wall, and the distance apart was probably five feet. The ceiling of a room, which may include three windows, contains probably fifteen outlets just protruding through the ceiling, or partly covered; thus there is provided a very nice combination of outlets from which to choose.

Mr. C. W. Hare:—It would be well to apply the knowledge of the illuminating engineer to the distribution of light for each individual room, and provide a sufficient number of outlets for either gas or electricity, or both, to illuminate the room sufficiently well for all purposes. Such a plan is preferable to installing a certain number of outlets for any possible use.

Mr. J. E. Woodwell:—Second to the question of the number of outlets and their location, is the matter of the control of the lamps. That point must be considered, first, with reference to the convenience in switch control, that it, the desirable location of the switch and number of lamps to be connected on one particular circuit, and second, the economical control of the circuit. Probably there is no one thing of more importance today in practical electrical installation than the matter of the proper and suitable control of the lamps on the different circuits, so that the arrangement will be both convenient and economical.

Mr. V. R. Lansingh:—I saw an installation the other day in which wires had been run directly in the floor. Small channels had been cut in the floor and all wires were placed therein,—so that no matter where a desk was placed, either telephone, electric lamp or phonograph connections could easily be made.

Mr. Strong:—Unquestionably the chief reason for altering outlets and injuring the building is insufficiency of light.

The suggestion that outlets in office buildings, particularly, should be kept off of outside walls is an excellent one, but a switch must be placed on some partition walls. The matter of control was not dealt with in the paper, as the paper did not attempt in any way to cover the whole subject, but I think, insofar as a residence is concerned, where the actual cost is not an important feature, it is a good idea to put in numerous switches. My experience with switches in an office building is that with the exception of one switch for a center outlet, they are unnecessary; as a rule the ceiling fixture which is used in the office can readily be controlled by hand, and it is well to economize somewhat in locating switches in an office building.

It is true that if more outlets are installed than may be needed the first cost is increased to some extent, but as I tried to point out in the paper the final cost will be less, considering the alterations that must be made if the outlets are proportioned strictly for only the original arrangement of the office.

My plan is to install a center outlet, and use in addition to that a row of outlets, say five feet apart, two feet from the wall, forming a rectangle around the center outlet; with that distance between outlets one will be able by means of a fixture to illuminate a piece of furniture or desk placed in any part of that room. While such a plan may add a little to the first cost, it will satisfy the owner better in the long run, since he can simply change the fixtures and need not cut the plaster or make holes in a brick or other kind of partition.

In the bed room of a residence it is true that the logical place for the bed is in one spot, as a rule, but my observation has been that furniture will be changed, notwithstanding that there is only one logical place for the bed; before the room is occupied the bed may be placed across a door connecting the adjoining room, and left in this position, while the bureau will be placed where the bed should be, and the lamp will be in the further corner of the room—a lamp shining on the back of a person when facing a mirror is not in the best position for lighting the face of that person.

The case mentioned of the United Gas Improvement Company's building in Philadelphia, coincides with my views.

I think mouldings should be used only where one is compelled to do so. They are unsightly, in the first place, and they are dangerous in the second place; they are relics of bygone days. I do not know of any modern office building that uses mouldings, unless the architect forgot electric lamps, or no electrical engineer was consulted. Those are the only reasons of which I can think for equipping a new building with mouldings. A building should be wired before it is finished, and concealed conduits should be used.

ARCHITECTURE AND ILLUMINATION.[1]

BY EMILE G. PERROT.

As the primary function of a building is to serve the practical uses of man, it is evident that the most successful building from this standpoint is the one that embodies to the last degree all improvements calculated to satisfy the needs of our complex civilization. Viewed strictly from the utilitarian standpoint, therefore, architecture and illumination are inseparable. If, however, architecture is considered in its real significance as being ornamental construction, one of the fine arts, and possessing in addition to its technical value, aesthetic and phonetic values,—that is, beauty and power to tell a story,—then illumination becomes only the handmaid of architecture, as are painting and sculpture.

Hence, it is seen that the relation of illumination and architecure may be considered from a twofold aspect. If we consider architecture with the most serious thought and take Ruskin's viewpoint of it, "we may live without her and worship without her, but we cannot remember without her," then we must consider the ability of our architecture to transmit to posterity the true life and histroy of our time, written in imperishable stone to be the conqueror of the forgetfulness of men. Only when this has been done will the highest function in the practice of the art have been fulfilled.

In order that a building may give pleasure to the beholder, it must possess the attributes of unity, grace, and proportion. Unity consists in the manifest connection of the parts into a whole. When the parts are arranged with a varied outline, they give pleasure from this cause; while proportion consists in so regulating the size of the parts that they appear in harmonious relation to each other. Hence it is by the possession of these three attributes to the proper degree that a building ranks as a work of art.

The architect's means of expression is by the use of the

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

materials of construction, which must be so moulded and shaped as to give the appearance of solidity; that is, that the building is a concrete reality, that it is solid and substantial in addition to being a thing of beauty. This effect is produced largely by means of shades and shadows; hence the knowledge of the "third dimension," as it is called, is necessary to the proper expression of a building. It is here that light plays a most important part in the bringing out of the details which characterize the work of the master architect. It was the understanding of the contour of details that made the Greeks surpass the Romans as artists, and is indicative of the perfection to which the Greek mind was developed as compared with that of the Roman. If a study is made of the capitals of the Doric order of Architecture, which were used by both the Greeks and the Romans, the shape of the ovolo mould in the former will be seen to possess that subtleness of outline that the light and shade changes so gradually as to produce a softness not obtainable in the bold outline used by the Romans, which latter was an expression of a less refined nature. The study of the play of light and shade on the exterior of a building requires the highest kind of training for the successful outcome of an architectural composition; the effect of the building in strong sunlight being usually considered.

With the interior of the building, however, it is different. The effect of the strong sunlight no longer exists, a diffused or subdued light takes its place. Hence, the design of details for the interior of a building should not possess the same characteristics as are found on the exterior of buildings. Here again the skillful architect seizes his opportunity to display his talent by so modifying the details that they may be best brought out under the different light conditions.

The aspect of a building when viewed in daytime will be different from that at night with artificial illumination. Therefore, the architect should study the method of lighting in relation to its effect on the aspect of the design, in just the same manner as he does the effect of sunlight. This phase of the art of lighting, it must be confessed, has been very much neglected by the architect. It is to be hoped that greater care will be used, and more study put into the illumination of buildings, by our architects so that the result, when the building is completed, will be

one in which no shortcoming from this cause will be visible. Much can be done by this Society to further this end among the architects.

For the purposes of this paper, illumination may be divided into two parts,—"necessary lighting," and "decorative lighting." Under the first head is included all methods of lighting which are used in buildings irrespective of the effect upon the architecture; in other words, the scientific application of the sources of light for the purposes of rendering possible the use of the building at night time.

The second division comprises that use of artificial lighting for the purposes of display, without any reference to the scientific or economic aspect. Of course, the latter method of lighting also performs the function of the former.

The method of lighting outlined under the first heading is the one that has been employed in the majority of cases; in many instances it seriously counteracts the effects of the architecture by compelling the use of large and unsightly fixtures in locations ill adapted for them. This result is very noticeable in large buildings whose prototypes are the monuments of ancient Rome and Greece, in which the use of elaborate chandeliers are unknown. However, lighting fixtures, if properly placed, and designed for the location, are one of the best means of adding to the furnishings of an apartment. The architect should design the fixtures for a building just as he designs the carving for a column capital or the bas-relief enrichment of a frieze, for the use of stock patterns for any feature of a building is reprehensible. On the other hand nothing is more striking in a building than a lighting fixture when in use at night time.

As a rule, the general practice heretofore has been for the architect either to make a selection from fixtures that are in stock or to entrust the designing of the fixtures to specialists in this line.

In many cases the architect is not consulted at all, the owner or committee arrogating this right to themselves, very frequently to save the architect's commission. However, in more important work the architect's influence on the selection of fixtures is felt more than ever, to the extent thus far that the architect even

designs the hardware for the building, just as he would a stair-rail or iron-grille.

A very successful combination of architecture and illumination exists in the new Singer Building, New York. The lighting of the main entrance lobby is particularly striking by reason of the absence of electroliers, while the architect has made use of concealed lamps over a diffusing glass forming the center of each vault; thus a flood of light emanates from the center of each vault, bringing out very effectively the details of the building. The decorative or display lighting of the exterior of the building is effectively accomplished in the combined use of lamps to outline the architecture of the roof, and search lanterns to illumine the shafts of the high tower, bringing out, even in night time, the effect of the color scheme. While one may question from an architectural standpoint the wisdom of the display on a building of this type, there can be no doubt that the scheme is appropriate in the case of the lighting of such pleasure buildings as are seen in the summer parks, such as the towers in Coney Island. The kaleidoscopic treatment of the designs in electric lamps is in keeping with the latter type of building, and the general use of lamps to outline the architecture and form part of the general treatment of the design is to be commended.

One of the most successful uses of decorative lighting on a large scale was in connection with the Buffalo Exposition of 1901. On account of the nearness of the Exposition to Niagara Falls, it was possible to produce effects on a large scale hardly possible when the cost of production is so much greater. In the Exposition it can be truly said that illumination was the handmaid of architecture, for no one standing at the entrance to the forecourt at sunset, with the strains of the band playing the soul-stirring national anthem, was not stirred when he looked upon the dim outlines of the buildings as they receded one back of another with the tall tower looming up in the distance about to lift its pinnacle of light to Heaven to proclaim to the world the supremacy of man's genius as exemplified and typified in the pillars of light. The sight was particularly impressive when in the midst of this gloom the soft glow of the electric lamps encompassed the entire scene, and, as if possessed of a single

moving spirit, the glow gradually grew to a brighter and brightter light until the entire surroundings, buildings, landscape, and statuary, glistened in the brilliancy of thousands of electric lamps that served not only to delineate the buildings but to illumine the heavens for miles around. Anyone who was fortunate enough to witness it will agree with the statement that for the perfect union of architecture and illumination the Buffalo Exposition has never been surpassed.

My idea as to one way in which this Society could materially help the architects, as mentioned in a previous part of this paper, is by the publication of tables embodying standards and by giving data and formulas for the lighting of all types of buildings by the various illuminants. Such pamphlets should contain examples of lighting schemes in existing buildings. Of course, the publication of such data would involve considerable labor and cost, but I think a committee of this Society could be appointed which would be able to accomplish this end, if the members consisted of those who had previously performed this service for the large manufacturing and lighting companies. I hope the convention will take some steps towards furthering this end. If buildings are to be properly lighted and made to embody the latest improvements, the architects should be kept in touch with all that is new and desirable for the purpose of effectively and economically lighting the buildings he designs, with the view of wedding together architecture and illumination, and thus leave to posterity the fullness of what has hitherto been but a faint effort of the proper union of the noblest of the fine arts, and the most useful of the sciences. I believe that this result can be better accomplished through this Society than by any other means.

DISCUSSION

Mr. Albert J. Marshall:—In connection with the remark by Mr. Perrot, that, "when the illuminating engineer has something of importance to do dealing with architecture, he should consult an architect" it might be well to note that it is a poor rule that does not work both ways, and that it would not be out of place to remark that when the architect has something of importance to do dealing with artificial lighting, it might be well

for him to consult an illuminating engineer. By consulting such an independent source, the architect would not be under obligations to commercial interests which have heretofore ofttimes supplied engineering information primarily as a means of selling their product.

Mr. Perrot states that lighting may be confined to two general heads, namely, "necessary lighting" and "decorative lighting," and that "under the first head, namely, necessary lighting, are included all methods of lighting which are used in buildings irrespective of the effect upon the architecture." In other words, the scientific application of the sources of light for the purpose of rendering possible the use of the building at night time." Personally I cannot conceive of any building in which artificial light may be used that does not have some architecture or decorative treatment to be considered when the lighting system is being designed, even though the building be of the crudest form; even if one were designing a lighting system for a barn, it would be desirable to recommend a system which would be harmonious with its surroundings. I think that too great stress cannot be laid on this most important point, namely, making a lighting system harmonize with its general surroundings in as full detail as possible.

Mr. L. R. Hopton:—My only criticism of this excellent paper is that it is not long enough to deal adequately with so large a subject as the relation between architecture and illumination. Mr. Perrot in his last paragraph has hit the nail squarely on the head, for while the illuminating engineer can exercise almost unrestricted his engineering function in designing illuminating schemes for all buildings of a commercial character he must work hand in hand with the architects on all but commercial work. I think that the Society can do nothing better than to publish the results of successful work done by prominent illuminating engineers in consultation with prominent architects. Such data would be of great educational value both to illuminating engineers and to architects.

Mr. Emile G. Perrot:—In the first place I wish it understood that the co-operation of the engineer and architect in any scheme is necessary. I myself by training am a structural engineer as

well as an architect. The same difficulties which this Society is encountering in the case of the architects was felt long ago, and is felt to some extent today, by the big structural engineering firms who design the modern sky-scrappers, and the co-operation of the architect and engineer in these big undertakings is of vital importance. However, there are members of the architect profession who unfortunately, I must say, have very little liking for the structural or scientific. I shall endeavor to make clear my point regarding "necessary lighting" and "decorative lighting" or display lighting, as I do not think the meaning has been grasped exactly.

I did not refer to the fact of whether the fixture was in Louis XVI style or art nouveau style or the French Empire style, or whatever it may be, I referred to the effect of the light on the mouldings, and the shape of the mouldings should correspond to a certain condition of light. As is well known, an object can be made to appear distorted by giving it the wrong viewpoint. Now, the lamps may be placed in a building so as to produce shadows on the wrong side of the mouldings and thus make them look something different from what they are.

Regarding the publication of various tables, etc., of which I spoke, I am well aware that each person has his own little sphere in which to labor. The illuminating engineer has his sphere just as does the architect, but I am a firm believer that when any body of men show that they are important, make themselves felt, they become servants of those who need them.

The architect needs the services of the illuminating engineer badly. It is to be regretted that architects do not call in the illuminating engineer in the earlier stages of their architectural schemes.

I repeat that this body of illuminating engineers, if they wish to make themselves felt, should act somewhat in the same manner as did the structural engineers and big steel corporations, by sending out literature in the shape of hand books, thus making every little architect, no matter whether he designed only a wooden cottage, to realize that the steel beam was the thing to use in the proper place, and he had a book in which he could find a description and tables of strength of the steel beams for certain

places. They created a demand through educating the architect concerning a matter about which, say 50 per cent. of the architects in the country, knew very little. A similar result would follow a similar action by the illuminating engineers. From a scientific standpoint, the architects know very little about illumination and if the Society were in a position to educate them, it would eliminate that defect in the knowledge of the architect concerning the matter of illumination.

THE IVES COLORIMETER IN ILLUMINATING ENGINEERING.[1]

BY DR. HERBERT E. IVES.

The Ives colorimeter is an instrument designed by Mr. Frederic E. Ives for the measurement of all colors in terms of three primary colors. As has long been known, spectral red, green and blue light mixed in various proportions will reproduce to the eye all the hues met in nature. This fact, hitherto made use of in the scientific laboratory for the study of color sensations, and applied commercially in the practice of trichromatic photography, has not before been utilized in the practical measurement of color.

By means of the colorimeter it is possible to describe a color accurately in terms of the red, green, and blue components of a standard white light. For instance, in place of the indefinite term "pink," a color may be designated as

Red 62; Green 31; Blue 50

white being

Red 100; Green 100; Blue 100.

These figures mean that by mixing red, green, and blue light in the proportions given there is produced to the eye the sensation of pink.

Two colors alike to the eye measure alike in the colorimeter. In this it differs from the spectrophotometer, which gives the intensity at every point in the spectrum but only an approximate indication of how the eye will compare the color in question with another. In the colorimeter, therefore, we have a means hitherto lacking, of comparing numerically the visual effect of such dissimilar sources of light as a gas flame and a mercury vacuum arc.

Although designed to measure colored fabrics by reflected light, the colorimeter may be used to study the colors of various illuminants, and in problems connected with their use. The present investigation, suggested by Dr. E. P. Hyde, has for its object

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

a preliminary study of the color of various artificial sources, and the change in appearance of colored objects when illuminated by them.

A brief description of the instrument will be necessary. It consists essentially of an oblong box, at one end of which are placed four slits, one clear, the three others furnished, respectively, with a red, a green and a blue color screen. By means of levers the openings of the three colored slits may be altered to read by scales from zero to one hundred. Within the instrument is a wheel of lenses which when rotated rapidly by a small motor causes the three colors to pass across the field of vision of an eyepiece, thus mixing them by persistence of vision. The optical arrangements are such that one observes a divided field, one-half consisting of the mixture of three colors, the other the color to be matched, as viewed through the clear slit. For ordinary use a white surface reflecting the light of the sky serves as standard white, the fabric observed being illuminated by the same light. To make a measurement, the three levers are opened until white is matched, and the scales are adjusted to read 100 for each color (this method compensates for slight differences in color vision of different eyes) ; then any color matched by moving the three levers can be read off in terms of the red, green and blue used to match white.

For measuring colored lights this arrangement of apparatus needed modification. Since two different sources were in use, the measured light and a comparison source—the region in front of the instrument was divided by a partition. The light studied was allowed to fall on a flat surface of magnesium oxide placed before the clear slit. On the other side was placed the comparison light, to be described shortly.

The question of a suitable standard to serve for comparison light presented certain difficulties. Average daylight is the logical standard. Daylight, however, varies greatly in character from average, and moreover is apt to be so changeable during even a short interval as to render it useless for a series of comparative measurements. It was therefore decided to use some reliable constant source, afterward reducing the figures obtained to average daylight. A practical consideration was that the comparison light should, if possible, be intermediate in charac-

ter between the extremes of color to be measured. The light finally decided on was that of a tungsten lamp operated at 1.13 watts per mean spherical candle. The lamp used had a frosted globe, and was placed about two inches in front of the colored slits. A strip of flashed opal glass served to diffuse and equalize the illumination of the slits.

With the apparatus so arranged the light from any illuminant could be measured and compared with any other. As illustration, the readings of a gas flame and a Nernst glower were respectively (red, green, blue), 30.7, 38.7, 19 and 44.7, 71.7, 56.3. Choosing such an absolute brightness as will bring the two sources to equality in the red the following ratio is found:

	Red	Green	Blue
Gas ÷ Nernst.....	1	.78	.51

Table I gives the results of a set of measurements on twenty-one different sources of light, expressed in terms of average daylight, the latter obtained in the way to be described below.

It was at first hoped to express the results in terms of the average daylight obtained by Professor E. L. Nichols from spectrophotometer readings, and reported in the May number of the "*Transactions of the Illuminating Engineering Society.*" It was intended either to reproduce this light by placing a color screen before a source in terms of which it has been expressed; or to calculate from color-mixture curves the proper openings of the three slits to duplicate average daylight when using some chosen source. Practical difficulties arose in each case, but the attempt was finally given up for another reason. This reason was that Professor Nichol's average daylight, as nearly as could be determined, is much yellower than any daylight observed in Washington during the period of work, and is indeed considerably more yellow than sunlight. This fact was first noted when a fairly close match for Dr. Nichol's "average daylight" was made by allowing the light from an acetylene flame to pass through two pieces of American Optical Company's blue glass, (Nos. 5 and 1). From Dr. Nichol's data the ratio of "average daylight" to acetylene throughout the spectrum was obtained; then with the aid of the spectrophotometer various colored glasses were tried until the above were chosen as approximating closely to the desired absorption. Although the resultant intensity curve

deviates somewhat from "average daylight," the integral effect on the eye must be very nearly the same. This light compared in a photometer with various kinds of daylight was always too yellow. This observation seems to be corroborated by Miss Koettgen's measurements of sunlight in terms of the Hefner. From her values it appears that for equality in the red ($\lambda=0.7\mu$), sunlight has about seventy times as much blue ($\lambda=0.42\mu$) as the Hefner; according to Dr. Nichol's figures "daylight" has only twenty-five times as much blue, yet daylight is "always bluer than sunlight." It was, therefore, thought best (as most convenient) to use as the standard the average daylight during the time the work was carried on. Whether or not in agreement with true average daylight, as ultimately determined the relative values of the other sources among themselves will be unaffected.

The "average daylight" of the table is obtained from fifteen sets of observations made during an interval of three weeks; they fall naturally into three groups; blue sky, partly cloudy or foggy sky, and entirely overcast sky. The averages of these groups, in terms of the comparison source, were

	Red	Green	Blue
Blue sky	7.9	25.8	100
Cloudy	9.3	27.8	100
Overcast	11.2	30.4	100
Mean	9.5	28	100

As the instrument is ordinarily used daylight reads 100, 100, 100, and it was thought desirable to preserve this scale in the present investigation. The above means were therefore multiplied by the proper factors to bring them each to 100, and all readings of other lights were multiplied by the same factors. To facilitate comparison the values for red were made equal for all of the lights.

In the table the sources are arranged roughly in the order of their approximation to daylight; sunlight and the carbon arc are near the head of the list, the Hefner at the foot. The figures for the Moore tube were obtained indirectly from observations made in the New York Post Office by Mr. F. E. Ives, with a glow lamp as a comparison source. The helium tube is included because it has been suggested as a primary standard. The tungsten, Nernst, tantalum, graphitized filament and car-

bon glow lamps were run at their normal specific consumption as determined by measurement of each lamp for mean spherical candle-power, current and voltage. This was found of the utmost importance, for two reasons: first, because the color depends on the specific consumption; secondly, because in all but one case the manufacturers' rated voltages were far enough wrong to place the lamps in a different order from the correct one. At the conclusion of the measurement the five lights were compared directly with each other for color, on a photometer bench, and their relative positions in the list were found to be correct.

The red, green and blue readings are each the mean of from five to ten observations, and should be accurate to about one per cent

TABLE I—COLORIMETER READINGS ON VARIOUS SOURCES.

Source	Red	Green	Blue
Average daylight	100	100	100
Blue sky, mean of five sets	100	106	120
Overcast sky, mean of four sets	100	92	85
Sunlight, 2 P. M., August 19th	100	95	68
Sunlight, afternoon observations, 2 to 5 P. M	100	91	56
Nichols' average daylight (acetylene flame and A. O. Co. blue glasses 5 and 1)	100	69	42
Carbon arc, direct current	100	64	39
Mercury vacuum arc (Cooper Hewitt)	100	130	190
Moore carbon dioxide tube	100	120	520
Welsbach mantle, ¾ per cent. cerium	100	81	28
Welsbach mantle, 1¼ per cent. cerium (mantle preferred by Welsbach Co. for residential illumination)	100	69	14.5
Welsbach mantle, 1¾ per cent. cerium	100	63	12.3
Tungsten lamp, 1.57 watts per mean spherical c. p			
Tungsten lamp, 1.25 watts per mean horizontal c. p.	100	55	12.1
Nernst glower, bare, 118 volts, .4 ampere	100	51.5	11.3
Acetylene flame	100	50	10.4
Tantalum lamp, 2.5 watts per mean spherical c. p.			
Tantalum lamp, 2.0 watts per mean horizontal c. p.	100	49	8.3
Graphitized filament, 3.1 watts per mean spherical c. p.			
Graphitized filament, 2.5 watts per mean horizontal c. p.	100	48	8.3
Glow lamp, 3.9 watts per mean spherical c. p.			
Glow lamp, 3.1 watts per mean horizontal c. p.	100	45	7.4
Flaming arc	100	36.5	9
Helium tube	100	37.0	9
Gas flame, open fish-tail burner	100	40	5.8
Moore nitrogen tube	100	28	6.6
Hefner	100	35	3.8

Following the colorimeter measurements of the sources themselves, a brief study was made of color changes under artificial light. It is known that the color of a surface illuminated by most artificial sources differs greatly from its color under daylight. At the same time the change in all colors is approximately the same, so that they keep their relative places fairly closely. This fact may be expressed differently by saying that the change in color of a white surface under artificial light is a fair guide to the change in color of a colored surface. Exceptions to this will occur to everyone; nevertheless, unless the source of light is quite selective, or the reflective power of the surface very selective, the rule holds good.

It was thought of interest to measure with the colorimeter the change of color of colored surfaces, under different lights, and then to see how closely these changes followed the altered readings for a white surface under the same conditions. The results should show whether the colorimeter readings for a white surface under varied illumination give a good indication of the readings for a colored surface whose readings are known for daylight. For this purpose a number of colored cloths and papers were selected whose dominant hues ranged throughout the spectrum; of these, several were chosen because they showed great changes in appearance under different lights. Mounted on a disc together with a white surface they were read under daylight, the light from a tungsten lamp, a glow lamp, a Welsbach and a Cooper-Hewitt mercury arc.

As was to be expected the direct readings showed great differences in color according to the kind of illumination. A lavender silk, for instance, read:

	Red	Green	Blue
In daylight	3	7.2	31.8
Under Welsbach	10.2	15.4	17.6
Under glow lamp	20.2	20.9	16.2
Under mercury arc	6.5	5.5	44.

Making the readings equal in the red to fit them better for comparison, they became:

	Red	Green	Blue
Daylight	100	240	1060
Welsbach	100	151	173
Glow lamp	100	107	80
Mercury arc	100	845	676

A large portion of the enormous difference is, of course, due to the change in color of the light; in order to take this into account the following procedure was adopted: All measurements were reduced to the basis of white=100, 100, 100; that is all the daylight readings were multiplied as before by the factors to make the daylight readings on white 100, 100, 100, and similarly the artificial light readings were multiplied respectively by the factors necessary to make white as given by them read 100, 100, 100. This being done, it follows that if colored objects under different lights change their readings in the same proportion as does white, their readings so reduced should be the same in all cases. The method of reduction will perhaps be clearer for one illustration:

	R	G	V		R	G	V
White surface in daylight,	24.6	22.1	70.9;	under Welsbach	29.8	55	33
Colored surface in daylight,	20.4	14.5	34	under Welsbach	24.6	34.2	15
Making white =	100	100	100;		100	100	100

Colored surface becomes:

Red = $\frac{20.4}{24.6} \times 100 = 82.9$, etc.; 82.9 65.7 48.1; 82.5 62.8 44

In the following table the results are given for seven miscellaneous colors under five sources.

TABLE II—CHANGE OF COLORIMETER READINGS WITH VARIOUS ILLUMINANTS.

Figures are reduced to the basis of white reading 100, 100, 100 for each light.

	Red			Blue			Buff			Pink		
Daylight	37.0	5.9	7.6	11.0	15.8	35.1	82.9	65.7	48.1	77.3	48.0	61.9
Tungsten	41.9	6.7	6.4	8.6	12.0	36.7	83.	60.2	38.5	88.3	52.1	73.8
Welsbach	40.5	6.8	0	11.0	13.9	41.1	82.5	62.8	44.0	82.8	51.4	65.7
Glow	44.4	7.7	0	9.7	12.7	43.6	83.3	62.8	42.2	92.7	61.4	74.0
Mercury arc	17.4	4.5	8.3	21.5	11.0	33.9	87.4	73.6	42.9	68.2	49.4	77.0

TABLE II—(*Continued*).

	Pine wood			Lavender			Dull green		
Daylight	45.5	30.3	16.8	36.6	32.6	44.8	35.7	33.5	26.2
Tungsten	49.8	32.6	21.0	47.6	37.7	68.8	30.5	28.7	24.2
Welsbach	44.6	29.2	15.0	34.2	28.2	51.6	33.5	31.7	26.1
Glow	50.5	35.0	17.2	49.0	41.4	79.4	30.3	31.1	29.9
Mercury	36.5	32.3	12.4	38.9	27.7	48.9	35.9	31.8	22.1

It will be observed that, in place of the extreme differences obtained in the direct readings, the colors reading are not greatly different under different lights. In other words the colorimeter

readings roughly follow the change of illumination, as does the eye.

From these figures the best light of the five for matching colors is that of the Welsbach, while that of the Cooper-Hewitt, an extremely selective source, exhibits wide deviations That the latter should be the case is to be expected. The radiation from the mercury arc consists of a few bright lines in the spectrum, and the effect on a white surface may be indistinguishable to the eye from the illumination obtained from a source with a continuous spectrum. A colored surface, having its predominant color in a different region of the spectrum from the mercury arc will not reflect its light but will reflect the light of the similarly appearing source with the continuous spectrum. It will appear dark under one source, bright under the other. Hence in the case of a selective source the color of a white surface is no guide, either for the eye or for the colorimeter, to the effect on a colored surface.

Needless to say, the result of a set of measurements like the above depends to some extent on the colors chosen to be illuminated. To be complete the investigation should deal with a large range of colors representative of those found under average conditions. The examples chosen are sufficient, however, to establish that the colorimeter readings of a white surface under an artificial source, are an indication of the readings of colored surfaces, provided the source is not too selective.

The result of the work thus far done with the colorimeter as applied to illuminating engineering may be summarized here: By means of the colorimeter the colors of all types of sources may be described in terms of a given standard such as daylight. The figures expressing the color of a light are a fair indication of the change in the color of objects illuminated by it.

The question may be raised as to just what the colorimeter readings mean, for instance, in terms of the spectrophotometer, or of the primary color sensations. Strictly speaking, all that they give are the mixing proportions of three special color screens. Measured on the spectrophotometer these screens are found to possess transmissions which are fairly narrow and well separated, whose maxima (taking into account the sensibility of the eye) fall at Red = 0.635μ, green = 0.535μ, blue =

0.455^{μ}, or very closely at the wave lengths Maxwell chose for his primaries. As these color screens are probably the best available for the purpose, and as the instrument is expected to come into general use for the measurement of color, the colorimeter readings will constitute of themselves a sufficiently definite standard for many purposes. It is desirable however, to be able to reduce the readings to some fundamental standard. With this object in view the writer is now engaged in finding the values of the screens in terms of the three primary color sensations. When this has been completed it will be posssible to reduce colorimeter readings directly to color sensations, or, given the spectrophotometer readings of a color, to obtain from color sensation curves the colorimeter readings.

DISCUSSION.

Mr. D. McFarlan Moore:—The Ives colorimeter with its wheel of lenses can be made a very valuable instrument to the illuminating engineer. However, the list of light sources, combined with certain statements in the paper, is extremely misleading. The carbon dioxide tube should have been first in the list of approximation to daylight. From the statement: "In the table the sources are arranged roughly in the order of their approximation to daylight" and the subsequent statement: "The figures expressing the color of a light are a fair indication of the change in the color of objects illuminated by it," I draw the conclusion that, according to the paper, the mercury arc would be preferable to a carbon dioxide tube over a ribbon counter in a dry goods store—a conclusion which we all know to be ridiculous.

For several years the carbon dioxide tube has proved its superiority over the arc lamp. As a substitute for natural light, it is second to none, and it is far superior to all others. I do not claim to have discovered this fact, for it has been known and well authenticated for many years. In fact, it had its origin in almost the beginning of our science. It was known to Geissler and Plucker and Crookes, Kelvin, Norrie, Birchmore, Perry, Anthony and many others. Recent spectroscopic tests have been made on the carbon dioxide tube, notably those of Prof. Fleming, in England, and the experts of the General Elec-

tric Company, in America, who found that the spectrum of carbon dioxide, when passing an electric current, differed very slightly from average diffused daylight. Probably the most accurate and exhaustive tests of this kind were made by the experts of the Siemens-Schuckert Company in Germany. These tests were carried out by Prof. Utzinger. He also used colored screens in a manner very much similar to those used in the Ives colorimeter, except that he did not use the revolving wheel of lenses. However, the figures obtained by Prof. Utzinger differed very widely indeed from those stated in the paper. He obtained 103 for the green, not 120, and 104 for the red, not 520. He made the statement that the carbon dioxide tube did not differ from average daylight by more than three per cent. on a cloudless day, and not 400 or 500 per cent., as one would be justified in deducing from the statements given in the paper. He also plotted a curve showing the character of what he considered average daylight illumination, and also a curve for the carbon dioxide tube. These two curves on certain days, under certain conditions, are almost identical, though generally the carbon dioxide curve was slightly higher at the blue end of the spectrum, while at the red end of the spectrum it was slightly lower. The two curves crossed midway between the yellow and the green. Perhaps the errors in the paper were clerical. It is stated that the values were obtained indirectly, and that the figures for the moore tube were obtained "indirectly with a glow lamp as a comparison source." There was no glow lamp used as a comparison source in the measurements made in the carbon dioxide tube in the New York Post Office. The comparison source used was a hand-adjusted arc lamp, the light of which was very variable.

Aside from this, statements made at the time of the tests by Mr. Ives were to the effect that the carbon dioxide tube was superior to the arc lamp as a source of light that approximated daylight. But aside from all the technical data and figures given above, the commercial tests on the carbon dioxide tube during the past several years amply proves that is is far ahead of any other source of light for such purposes. An ordinary arc lamp over a ribbon counter has been proven many times to be inadequate for matching silks and ribbons.

I mention the above as evidence to prove that the conclusion which may be drawn from the paper, namely the carbon dioxide tube should be third on the list, is an error. It should be first on the list. There is no place where it is more important to match colors than in the silk industry, and it has been found that the carbon dioxide tube is in some respects superior to daylight in this business.

The carbon dioxide tube should be seriously considered by this Society as a standard of light, not only so far as intensity and reproductibility is concerned, but also as regards color values. All other forms of light should be expressed in terms of that of the carbon dioxide tube. A few years ago such a statement would have been met with the objection that the light of the tube was too white, but the recent developments of all forms of light show a tendency to approach a pure white light. The tungsten lamp gives a great deal whiter light than does the carbon lamp.

Dr. E. P. Hyde:—There is one point to which Mr. Moore has just referred on which I think I can throw a little light. I believe that Mr. Moore did not entirely understand the use that was made of the carbon-filament lamp in the test at the New York Post Office. I was present at the time, and in fact the tests there were made under my direction, and I feel it encumbent on me to explain, in answer to Mr. Moore, the circumstances under which the test was made.

The carbon-filament lamp was used as a comparison source, but not in just the way that Mr. Moore understands it to have been used. I believe, and I think most of us believe, that the best way to make a measurement is by the use of the substitution method. The way the measurements were made in the New York Post Office was as follows: The three colored slits were illuminated with light from an arc lamp, the crater of an arc lamp, and the other slit, the white slit, was illuminated first by light from the carbon dioxide tube, then by light from the nitrogen tube and finally by light from an incandscent lamp. Since even the light from an arc lamp is not of a definite quality, and we did not want to depend upon the assumption that the light from all arc lamps is the same, and since we could not well carry the arc lamp to Washington under the conditions under which it was used

in New York, we used as a comparison source an incandescent lamp at a definite voltage. Subsequently this lamp was taken to Washington where Dr. Ives made measurements on it at the voltage at which it had been used, and under conditions approaching as exactly as possible those under which the tests in New York had been made. I think Dr. Ives would have said, if he had replied to the criticism, that he should not like to insist on the values as being quite as accurate when he uses the incandescent lamp, as they would have been if he had used some source more nearly like the Moore tube, because of the small amount of blue in the light from the incandescent lamp. At the same time, I believe that the figures given by Dr. Ives are not very far from correct.

I should like to answer Mr. Moore on another point to which he referred in the beginning of his discussion. He called attention to the statement that the values give a fair indication of the color of the source, and of the color which objects will assume under the source, but he did not read far enough. In the very next sentence Dr. Ives says: "Exceptions to this will occur to every one; nevertheless, unless the source of light is quite selective, or the reflective power of the surface very selective, the rule holds good." Now it is known that the mercury-vapor tube comes under this category, and consequently, as Dr. Ives stated in the paper, the Ives colorimeter cannot be used to give any indication of what color objects would assume under the mercury-vapor tube or under the light of any other source that is distinctively selective, and that is one fact that must be recognized in using the Ives colorimeter in illuminating engineering.

There *is* a field for the Ives colorimeter. Any one who visited the exhibition in the adjoining room, and has viewed the motley array of effects produced when different illuminants illuminate the same fabric, must have been convinced that there are other elements in illumination than mere quantitative efficiency, and one of these elements is the color of the light and the color of the objects illuminated by the light.

As Dr. Ives stated, the only method at our disposal heretofore has been the spectro-photometric method; not only is this method cumbersome and inconvenient, but with the measurements made

on the spectro-photometer it is difficult to get any interpretation which will be of practical benefit, because the interpretation involves a computation from the data given by the sensation curves, and this computation is difficult for any one to make, and certainly would not be adapted to commercial usage. In the Ives colorimeter there is available an instrument for giving a fairly reliable value to the color of light.

I think that the general conclusions from Dr. Ives' paper are these—first, that the Ives colorimeter gives a very good indication of the integral color, that is the color of a white surface illuminated by the source; and secondly, that unless the source is very selective in its emission, that is, radiates only in particular lines that are rather sparsely located in the spectrum, and unless the surfaces which are illuminated are quite selective, which is not the case in most surfaces with which we have to deal, the Ives colorimeter gives not only a good value for the integral light, but also a good indication of what we can expect surfaces to look like under the various artificial lamps, so that the Ives colorimeter, while not telling everything one wishes to know, and while having to be used with caution, is certainly a valuable adjunct to the various instruments at present available in illuminating engineering.

Mr. J. E. Woodwell:—It is possible that one practical point about this test has been overlooked, and I venture to make a remark upon it, in the hope that it may aid in clearing up the apparent difference of opinion expressed by several of the parties who have discussed this paper so far.

I was present at the time the tests were made, and know that the arrangements for the colorimeter measurements were perfected at the last moment, under conditions which were not altogether favorable. Previous to this test all of the tubes in the Post Office had been running as nitrogen tubes, and I believe I am stating the case correctly, that one of the nitrogen tubes was changed to a carbon dioxide tube, with a resulting composite gas, so that the result may have been different from what would have been secured if use had been made of an exclusively carbon dioxide tube which had been running for sufficient time, to become constant in its performance.

The figures in Dr. Ives' paper are stated in terms of red as 100. Now, if the red had been increased very slightly, the effect might have been considerable on the other two values. I am in hopes that this explanation will clear up some of the misunderstanding.

Mr. Frederick Ives:—I am not a member of the Society, but having made the tests referred to I should like to say a few words. It seems to me that the light of the carbon dioxide tube comes nearer to daylight than that of any of the other artificial illuminants used in our tests. My impression of the carbon dioxide tube was that because of its steadiness and because the light was rich in blue, it was the most satisfactory source of artificial illumination for the comparison of colors of anything I had seen, but my impression was that it represented the color of a moderatly blue sky. When I made the actual tests, I matched up the two fields of the instrument on the electric arc lamp and put the light of the carbon dioxide tube over the clear slot, and the comparison of the two fields showed that the light of the tube was very much bluer than that of the arc lamp, so as to make the light of the electric arc lamp appear by comparison distinctly yellow.

President Bell:—It does not necessarily follow that for all colors the same light will produce uniform results in the matching of colors. For example, certain lines of goods, running to certain shades, such as the goods one finds displayed in the tailor's shop, and the goods at the ribbon counter show up best under two dfferent kinds of light. I think that everybody who has had experience with actual color matching will recognize this fact, which should be borne in mind whenever the concrete effects of light are to be considered.

Mr. D. FcFarlan Moore:—I do not wish to be understood as making any criticism of the Ives instrument. The fact is, I think it will be a very useful instrument for the engineering profession, but I still think that the discussion which we have had clearly indicates that there has been some large error.

The quantity of blue that appears in a carbon dioxide tube depends on the kind of average daylight with which it is compared. For example there is a wide difference between the aver-

age daylight assumed by the author and the average daylight of Dr. Nichols.

One object of this Society is to change our art into a science as soon as possible, and the way to reduce anything to a science is to reduce the number of variables. This paper, in arriving at average daylight, has used three variables, blue sky, cloudy sky, and overcast sky. All scientific societies should agree on the cloudless sky. This has been done in a number of industrial plants, like silk factories; moreover the German practice has a tendency in that direction. The light from the carbon dioxide tube matches that of the average cloudless sky, and therefore since the tubes spectrum is constant and that of the cloudless sky is not, the light of the tube should be accepted as the standard for color values.

President Bell:—I agree with Mr. Moore that some convention regarding what is called secondary white is highly necessary. The figures given in this paper show how difficult it is to settle finally on it, and I hope they will lead to further industry on the part of Dr. Ives in the matter of straightening out the somewhat tangled question.

Mr. E. L. Elliott:—The object of the colorimeter, as I understand it, is to provide a practical means of analyzing color effects as a substitute for the highly technical method of spectroscopic analysis. I have always had the highest admiration for the researches of Mr. F. E. Ives in the domain of color. His work in this field has never received anything like the credit justly due to it. While I have not had the opportunity of examining the colorimeter, I confidently expected to find it a thoroughly reliable and practical device. I can hardly be persuaded that the figures given for the carbon dioxide tube are not purely a clerical or other similar error. It is difficult to imagine any two light-sources which differ wider in their color values than the mercury-vapor lamp and the carbon dioxide tube; if the colorimeter in actual use gives readings indicating that the mercury-vapor lamp has a whiter light than the carbon dioxide tube it certainly possesses some inherent weakness which would totally discredit the results obtained. I am anxious to hear of further trials of the instrument in this regard.

Dr. E. P. Hyde:—I can give Mr. Elliott a practical answer to his practical objection. During the time of the test, Mr. Woodwell, and I think there was some one else, and myself, stood in the room and had in perspective the carbon dioxide tube and the mercury-vapor tube. At that time the figures which are given in Dr. Ives' paper had not been worked out, so that we did not know where the sources stood as to the colorimeter values. The consensus of opinion, was that of the two sources the carbon dioxide tube was slightly bluer, and the mercury-vapor tube was slightly greener.

Mr. J. B. Klumpp:—Cannot the colorimeter be used to determine the color sensation of the eye? For instance, if a man is color-blind, and matched colors through a colorimeter, would this instrument determine the deficiency in this vision, and measure the degree of his color-blindness in percentages of the three primary color?

Dr. Herbert E. Ives:—A number of the objections raised by the first speaker, Mr. Moore, have been so fully answered by other speakers that it is needless to repeat them.

I shall take up several points, the last one first. As to color-blindness, the colorimeter is a practical form of the instruments that have been used in measuring color sensations. Our whole knowledge of color sensations and color vision, comes from measurements made with instruments of this sort. Furthermore the colorimeter as it stands is probably one of the most sensitive detectors of color-blindness in existence. A red-color-blind person will take a different amount of the light through the red glass to match the white on the other side than will a person with normal vision, and allowance is made for this fact in the construction of the colorimeter. As long as this difference in the eyesight of different observers is not great, it can be allowed for in the adjustment of the instrument.

There seems to be a great deal of difference of opinion concerning the carbon dioxide tube, and concordance of opinion among different observers. I have just two remarks to make. One can get no idea of the relative values of two different colors unless he compares one with the other. He can go into a brilliantly lighted room and get an impression of the color of the

light. If he goes away for an hour, and then come into another room equally brilliantly lighted by a different source of light, he would say they are precisely alike. Put the two lamps together, and the difference will be such as to startle one.

What the colorimeter does is to give the *mixing proportions* of the three primary colors. To reason from spectro-photometer values, to colorimeter values, involves intermediate work with the color sensation curves, and I think that some of the discrepancies may be traced to that fact. As I said in the paper, and as has been brought out here, the values for the carbon dioxide tube were determined indirectly, and not in the same series as the others, and I am well aware that there may be certain errors of proportion; the blue may not be 500, but 480, or something of that kind. However, the fact is that the light from the tube is bluer than that of the mercury arc.

All of the readings in the paper reduced to the basis of average daylight. Mr. Moore says that a cloudless sky should be taken as our standard. I have read Prof. Nichols' paper, which was presented before this Society last winter, and in the first table he gives different values for the relationship of skylight to sunlight, sunlight being taken as a standard, and the ratio of blue to red varies as much as 5 to 1, indicating that the blue sky is not a definite standard. Prof. Nichols attempted to get an average for daylight, and his idea was to use light from a cloudy sky, a clear sky, and various other kinds of daylight. I attempted to do the same thing, and therefore employed the mean of the daylight I could meassure in the time during which the experiments were being made.

Mr. Frederick E. Ives:—(Communicated after adjournment). Inasmuch as the discussion of Dr. Ives' paper centered around the value given for the light from the Moore carbon dioxide tube, the only measurement for which the author of the paper is not personally responsible, it is incumbent upon me to explain the condition under which the light was originally measured at the New York Post Office, and to report upon a new measurement subsequently made under more favorable conditions; the later results being more in accordance with opinions expressed in the discussions.

The original measurements, which were three times "transcribed," made the light of the Moore tube appear about five times as blue (relatively to the red) as average daylight. However accurate the original measurements in terms of the light of an electric arc lamp may have been, the fact that the lamp operated very badly and that the light was extraordinarily changeable in hue and intensity both then and when afterwards compared with the light of an incandescent lamp, made it possible and even probable that by the light of the arc lamp being yellow when the Moore tube was photometered and violet when the incandescent lamp was photometered a large error might have been introduced. There also existed the disturbing effect of stroboscopic phenomena, and although the Moore tube lamp was observed directly the light of the arc lamp was reflected upon opal glass, and an opal glass was interposed between the incandescent lamp and the colorimeter. I was not satisfied with the conditions at the time but nothing better could then be provided, and I did not suppose that great errors would be introduced.

Since the meeting in Philadelphia I have had an opportunity to measure the light from the Moore carbon dioxide tube in comparison with blue sky at zenith on a remarkably clear day and also with sunlight reflected from a dense opal glass upon the same day. As neither of the lights used in comparison is a definite standard the figures given have only an approximate value but they have the merit of being obtained by direct comparison. Suffice it to say, the light of the Moore tube was somewhat less blue than that of the sky at zenith, and twice as blue (red 100, blue 200) as sunlight reflected from the opal glass, therefore agreeing with my own estimate from direct observation that the light of the Moore tube has a hue coresponding to a moderately blue sky. I would not venture to give more definite figures without an opportunity to compare the light directly with a fixed standard not to far removed from the hue of average daylight.

With respect to the question of the relative blueness of the light of the mercury-vapor lamp and that of the Moore carbon dioxide tube, I may say that one tends toward "peacock" blue and the other toward "fundamental-sensation" blue. Peacock blue is fundamental-sensation blue plus fundamental-sensation green, but it is often described as "blue."

CALCULATING AND COMPARING LIGHTS FROM VARIOUS SOURCES.[1]

BY CARL HERING.

Our present system of measures and units, in terms of which light and its various numerical properties as an illuminant are expressed and measured, are apparently not as clearly understood as they should be, and the various terms and expressions involved, such as intensity, flux, quantity, illumination, density, etc., are often used with different meanings by different writers. Moreover some of the units or measures used do not seem to be clearly understood or defined, and it is believed by the writer that the real physical meanings of some of these quantities are not generally clearly understood. All of this creates a sort of mistiness concerning many of the calculations involving light in its various phases, which no doubt often deters one from making useful calculations that would be quite simple if one was sure of being correct. Physicists do valuable work for the engineer in discovering the laws of nature for him, but unfortunately they generally do not state them in such concise terms that the laws discovered by them can be used directly by the engineer in his numerical calculations.

The present paper is an attempt to clarify the apparent mistiness surrounding many of the calculations of light, by giving the formulas in such a form that they can be directly used for numerical calculations, and to explain in plain terms some of the less usual but often very useful and perhaps not generally understood laws; it is also an attempt to show what the real physical meaning is of the various quantities involved so that they may be used more intelligently, as their names sometimes mislead. It will then be shown by practical numerical examples how these various laws and formulas may be used for calculating and comparing lights from entirely different kinds of sources.

The well known law of the inverse square of the distance is well understood by all illuminating engineers and is no doubt

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908.

generally correctly used, but there are other laws, notably those concerning the light from surfaces, and those concerning the quantity of flux of light, which seem not to be generally and clearly understood, although they are often very useful and not at all difficult to understand. No attempts will be made to discuss the proofs of these laws, as the chief object of this paper is to show how calculations may be made in practice, hence their correctness will be assumed here by the writer. It is believed by thus reducing the formulas and laws to a simple form, based on a well defined system of units, many illuminating engineers who may not have had sufficient confidence to make many of these calculations, need no longer hesitate to do so.

Taking up first the three more important measures and their units, they are:

Flux, or radiation: common unit, 1 spherical candle; official unit, 1 lumen.

Intensity; common unit, 1 candle; official unit, 1 hefner.

Illumination; common unit, one foot-candle; official unit, one lux.

Flux represents the quantity of light radiation and is a very important quantity in the calculations of light; it was formerly but little used, but is gradually coming into more extended use, as it should, because it will greatly assist the illuminating engineer in his calculations. Flux of light is quite analogous to flux of magnetism or to flux or flow of electricity, more generally called a current of electricity. It can be shown that this measure is physically the same thing as power, that is, as watts or horse-powers, and can be converted into them just as inches and feet are physically the same kind of quantities and can be converted into each other; hence flux could be measured in watts, but at present it is more convenient and perhaps less confusing to measure it in a specifically named unit of light. The unit which has been used in practice, although not generally under the name of flux, is the spherical candle; another unit, differing only in its numerical value, is the lumen; as the latter does not involve the unfortunate name "candle" and for some calculations has a more convenient numerical value, it is less confusing and is often more simple to use than the spherical candle.

It is, therefore, desirable to introduce this less known unit more generally. In what follows, the formulas will generally be given in terms of both of these units so that either may be used; they of course must always lead to the same result.

Although not usually so considered, flux of light is that which is bought, sold and used,[1] and, therefore, is one of the most important and useful measures of light and should be more frequently used. A statement of the amount of flux alone, without any further specifications, is, however, not sufficient for industrial purposes; what enables one to see is not the amount of flux, but its density, hence it is necessary to specify the density also, or else the flux may be useless for the specific purpose, because if this density is not sufficient to see by, the flux is of no use no matter how large its quantity may be; in the same way, watt-hours of electrical energy are not a saleable product unless the voltage is also specified, or a quantity of steam unless the pressure is also stated. Hence the two important quantities in the sale, purchase and use of light, for most industrial purposes, are flux and flux density, the latter being represented, as will be described, either in candle power units or in illumination units (foot-candles).

Intensity is what might be popularly termed the brightness of the light, and is usually measured in this country in candle-powers. This is the measure with which illuminating engineers are most familiar, hence it needs no further description. It does not express or measure any particular quantity of light flux, illumination, angle of beam, etc., but merely an intensity and nothing more. The real physical meaning of candle-power is that it is a flux density expressed in terms of a solid angle, like that of a conical beam from a projector for instance; in fact it expresses the amount of flux per unit angle of the beam. It is often convenient to express the flux density in terms of this angle, and this is what candle-power really represents. Flux density may also be expressed in another way, as will be shown below; sometimes the one and sometimes the other is the more convenient. If intensity expressed in candle-powers is understood really to represent a flux density under the name of candle-power, it may sometimes

[1] Or more specifically, flux × time, that is, lumen-hours, or spherical candle hours.

assist in more clearly understanding problems occurring in practice.

It should be remembered that the laws concerning candle-power are based on the conception that the radiations issue from a point in straight lines, either in a limited or in all directions, and that if it is used for any other sources than a point, it is only what might be better called an "apparent" or "equivalent"; candle-power, and that the laws concerning this latter are not always the same in all respects as those for true point sources. In practice, if the source of light is not too large, or can be sufficiently far removed from the photometer, it may without great error be considered a point, as far as the photometric measurement is concerned, but not always in other respects, as will be shown below.

Illumination is popularly conceived to refer to light falling on a body, thereby illuminating it. But more specifically defined it is the amount of flux of light passing through a unit of area, like a square foot; that is, it is the flux divided by the cross section, and it is therefore in fact an expression of the density of the flux or the flux per square foot. It is quite analogous to the flux density of a magnetic field or to a current density. It does not express or measure any particular quantity of light flux, surface or intensity (candle-powers), but merely a flux density and nothing more; just as a specific gravity does not express any particular quantity of a material but merely its density. The term "illumination" is therefore an unfortunate one, as it misleads and tends to limit the conception of the real quantity. It can be correctly applied to any part of a beam of light whether or not there exists a body for it to fall on; it is so used in the well-known inverse square law; hence it does not necessarily imply any body at all. If a body is placed where it intercepts the flux and is illuminated by it, its illumination is measured in the same units as the flux density; this unit is here usually called the foot-candle, and is the flux per square foot at one foot from one candle. Such a body reflects more or less of the light; but what it reflects is of course also flux and as this comes from a specific surface, it also has a flux density; if the reflection is perfect, the flux is the same as formerly, hence as the surface is the same, the flux density will be the same too. If the body

absorbs some light then the flux density of the reflected light will be numerically less, but it will still be a flux density, hence what is called illumination applies also quite correctly to the light reflected from a surface; in fact it must be so considered or else some of our calculations and measures of light become hopelessly mistified or obscured.

All that a reflector does is to change the direction of light radiation, either regularly, as does a mirror, or irregularly, as does a white card; but it gives back flux of light as such, and this flux has a density determined by the surface; hence the reflected light has a flux density, which is the same kind of a quantity as illumination. It would be very desirable to distinguish between these two illuminations by distinctive names, but it should be remembered that they are both the same kind of quantities, like the watts which go into an electric transformer and those which come out; they might be called "incident" and "reflected" illumination, the difference between them being the absorption. When thus considered, there is no mysterious difference between the illumination falling on a wall and that reflected by it; both are correctly measurable in foot-candles, and their difference is merely numerical due to the loss by absorption and to one being generally directed light while the other is generally diffused light.

As a measure of flux density, illumination can be used for all kinds of beams of light whether conical or not, while its allied unit, namely, the candle-power, expresses the flux density more conveniently when the beam is conical and in fact can be used correctly only for such beams or their equivalents. The measure called illumination can be used for any light, whether it be a beam from a point as in the photometer measurements, or from a white surface from which light is diffusely reflected, or from a ground glass transmitting light, or for such light as daylight, or the surface of a primary source as a flame, the filament of an incandescent lamp, a large phosphorescent surface, a long tube lamp, etc. All such superficial lights may be correctly expressed and measured in illumination units, namely, foot-candles. It will be shown below that the other unit in which flat sources of light are often expressed and measured, namely, "candle-power per square inch" often called the brightness, is an un-

necessary and misleading unit, which introduces complications; the unit of illumination can always be used instead of it.

The three important fundamental relations existing between these three measures are as follows and are based on intensity (candle-power) as the fundamental quantity, the others being derived from it, which is the case in our present systems:

$$\text{illumination} = \frac{\text{intensity}}{\text{distance}^2} \qquad (1)$$

$$\text{flux} = (\text{intensity}) \times (\text{solid angle})^1 \qquad (2)$$

$$\text{illumination} = \frac{\text{flux}}{\text{surface}}\,. \qquad (3)$$

These three fundamental equations may be interchanged with each other, and will be found to agree with each other except for the quantity called the solid angle. This is a measure which is unfamiliar to most engineers and therefore gives rise to some confusion and uncertainty. But for present purposes it may be entirely eliminated from this set of formulas by remembering that

$$\text{solid angle} = \frac{\text{surface}}{\text{distance}^2} \qquad (4)$$

hence the second fundamental formula (2) becomes

$$\text{flux} = \frac{(\text{intensity}) \times (\text{surface})}{\text{distance}^2} \qquad (5)$$

Formulas may be developed from these relations for determining actual numerical values in terms of specific units, in which case it is very important that the same set of units be used throughout. If the common units stated above are used, the first formula will give the illumination directly in foot-candles if the intensity is given in candles and the distance in feet, hence

$$\text{foot-candles} = \frac{\text{candles}}{\text{feet}^2} \qquad (6)$$

From this any one of the three quantities can be calculated when the other two are known. Examples showing the application of this well known formula to practical problems are not necessary as this is described in all text books and is well understood.

[1] A solid angle is an angle in space like that at the point of a cone, or at the source of a conical beam of light.

In reducing the second fundamental formula to numerical values, the troublesome solid angle is involved and there unfortunately is a difference of opinion as to what unit is really in use at present in our common system. A discussion of this question may not be necessary here, but it may be well to explain that there are two units in use, one the absolute, which is an angle like that of a cone which subtends a unit of area like a square foot at a unit distance like one foot, and that this unit is called a steradian.[1] The second unit is the sphere which evidently is the maximum possible solid angle, just as a circle, or 360° is the maximum possible plane angle. For some purposes it is better to use the one and for other purposes the other. As a matter of fact one is using the sphere as this unit when he speaks of spherical candles for flux, as in the common expression "watts per candle," which means spherical candle-power; while he is using the absolute unit of solid angle when he refers to lumens. Our common system is unfortunately, therefore, not clear on this point and gives rise to some confusion in numerical calculations. It is quite correct to use either unit, provided only that it is definitely understood which one is meant; the only difference is in the numerical values of the units and therefore in the numerical constants in the formulas.

When the spherical candle-power is used as the unit of flux, that is, when the solid angle represented by a sphere is the unit, the second formula (2) becomes:

$$\text{spherical candles} = (\text{mean})\ \text{candles}. \tag{7}$$

This formula simply means that the flux in spherical candle units is numerically equal to the mean candle-power throughout this sphere, that is, in all directions.

When the other unit, the lumen, is used, then the unit solid angle is that which subtends a square foot at a distance of one foot and the second fundamental formula (2) then becomes

$$\text{lumens} = 4\pi \times (\text{mean})\ \text{candles} \tag{8}$$

meaning again, the mean candle-power measured in all directions. These two latter formulas, however, refer only to a light which

[1] A cone with a circular base having an angle of about 69° at its apex, represents such a unit solid angle; it takes about 12½ of these (accurately 4π) to make up a whole sphere.

can be considered as a free light radiating in all directions as does that from the usual lamps. For any other beams of light radiating in only a limited direction, these formulas become

$$\text{spherical candles} = \frac{\text{candles} \times \text{sq.ft.}}{4\pi \text{ feet}^2} = 0.07958 \frac{\text{cp.} \times \text{sq.ft.}}{\text{feet}^2} \quad (9)$$

and

$$\text{lumens} = \frac{\text{candles} \times \text{sq.ft.}}{\text{feet}^2} \quad (10)$$

It must be remembered that in these formulas the candle-power is considered either uniform or its value is the mean value for that beam. The square feet in the numerator represent the cross section of the conical beam at any fixed distance, and the feet in the denominator represent the distance from the source (that is, from the point of the conical beam) to the cross section. From these formulas it is understood that any one of the quantities involved can be calculated when the other three are given.

The numerical relations between these two different measures of flux are as follows:

$$1 \text{ spherical candle} = 4\pi \text{ (about } 12\tfrac{1}{2}\text{) lumens} \quad (11)$$

or

$$1 \text{ lumen} = 1 \div 4\pi \text{ (about 0.0796) spherical candle} \quad (12)$$

hence they may be converted from one to the other by the formulas

$$\text{lumens} = \text{spherical candles} \times 4\pi \quad (13)$$

and

$$\text{spherical candles} = \text{lumens} \div 4\pi. \quad (14)$$

In using the term lumen it should be understood that the same name is used abroad, where this unit was originally named, for a slightly different quantity based on the hefner unit instead of our candle; hence there will be the same difference between our common lumen and the official lumen as there is between our candle and the official hefner; that is,

$$\text{our common lumen} = \frac{\text{official lumen}}{0.88} = 1.136 \text{ official lumens.}$$

The third fundamental formula (3) when reduced to our common units becomes

$$\text{foot-candles} = \frac{4\pi \text{ spherical candles}}{\text{square feet}} \tag{15}$$

or in lumen units

$$\text{foot-candles} = \frac{\text{lumens}}{\text{sq. ft.}} \tag{16}$$

The surface referred to by the square feet is in this case the total surface on which this amount of flux falls, or through which it passes, or from which it issues in case the surface is a source of light.

The above formulas are of a general character and apply to these quantities in general, no matter what the nature of the source, except in one case in which the point source radiating in all directions was specified. Their use will be illustrated by numerical examples given below after certain differences between different kinds of sources, and certain other laws concerning light radiation, have been described.

A clear distinction is sometimes necessary between diffused light and what might be called directed light. The latter might be defined as light in which all the individual rays of a beam are definitely directed, like those radiating from a point, or those in "search-light" beams, telescopes, cameras, etc., while in the former the individual rays go promiscuously in many different directions and intersect each other indiscriminately, like those from a white paper, wall, cloud, a large surface of molten metal, a ground glass window, or globe, daylight, etc. Directed light casts a clear, definite shadow, while diffused light does not. If the source of light is small enough, like a gas flame, an incandescent electric lamp, a Welsbach mantle, etc., it may for all practical purposes be considered and treated as though it were a point of light. In general, directed light follows the laws of radiation from a point, while diffused light follows the laws of radiation from a surface. The numerical relations between them will be shown below.

There are in general three kinds of sources of light, a point, a line, and a surface, the laws concerning which are in some important respects different from each other. Any other source must be treated as the one which it approaches more nearly; sometimes a source may be treated as either, with sufficiently close approximation, in which case care must however be taken not to

go too far in the deductions from the results. A small line or surface for instance, like a carbon filament, a short tube lamp, a square inch of melted platinum, or an illuminated white card, may be correctly photometered in candle-powers as though they were point sources, if they are far enough off to be so considered. Moreover they may be revolved or otherwise integrated over a sphere so as to get their mean candle-power in all directions, from which the total flux can be calculated as usual.

When, however, lines and surfaces cannot be considered as points, or cannot have their mean spherical candle-power measured, it is important to notice what the differences are in the laws concerning them. One of them is this: the illumination produced at any place by a theoretical point of light varies inversely as the square of the distance to that place, while for a theoretical line of infinite length it is inversely as the distance and for a theoretical surface of infinite extent (such as the sky) it is independent of the distance, being the same everywhere in space. Or to put this into practical formulas in which numerical quantities can be substituted, and using as units the lumen, the foot, and the foot-candle (illumination unit), these laws are: for a point

$$\text{foot-candles} = \frac{\text{lumens}}{4\pi \text{ feet}^2} \qquad (17)$$

for an infinite line

$$\text{foot-candles} = \frac{\text{lumens per foot}}{2\pi \text{ feet}} \qquad (18)$$

and for an infinite surface

$$\text{foot-candles} = \text{lumens per square foot.} \qquad (19)$$

This latter simply means that when an infinitely large light giving surface like the sky illuminates a second surface, then the illumination of that second surface expressed in foot-candles is numerically the same as the lumens per square foot of the light giving surface, no matter what the distance. They both have the same flux density. Or in other words, the illuminated surface is just as luminous as the original source, assuming that it absorbs no light. Hence if the second surface is a hole in an opaque screen, and therefore absorbs no light, the surface of this hole will be equal to and will act like an equal part of the original surface, except

that it is now a limited surface the rays from which diverge according to the cosine law.

The candle-power in all these expressions, whether real or apparent, means that value which would be obtained by the usual calculation in the usual photometer measurement if such an infinite line were placed where the usual lamp is placed, (and of course perpendicular to the axis of the photometer), or if such a surface were placed at or anywhere behind the usual place for that lamp; the candle-power then means that value which an ordinary lamp (point source) would have to possess in order to give that measured illumination at the photometer screen, if it replaced that line or surface, or, if the surface was at an indefinite distance, like the sky, then it refers to a lamp at a distance of one foot, because that surface could have been brought to a distance of one foot without changing the illumination. For the line and the surface it might therefore be called an "equivalent" or "apparent" candle-power, because it refers to an equivalent only as far as the illumination at the particular place under consideration is concerned and nothing more; this equivalency does not refer to the flux or to its distribution.

The other important differences between point, line and surface sources refer to the total flux from the source when this flux is calculated, as it usually is, from the normal measured apparent candle-power. Using the lumen as the unit of flux and assuming again that the candle-power of the source is that value measured by the photometer, normally, when it is a line or surface, then the formulas are:

for a point

$$\text{lumens} = \text{candles} \times 4\pi \tag{20}$$

for each foot of the infinite line

$$\text{lumens} = \text{apparent candles (of whole line)} \times 2\pi \div \text{feet} \tag{21}$$

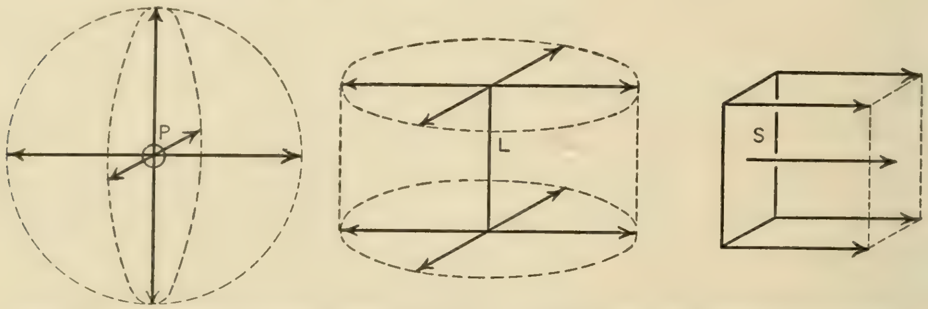
and for each square foot of the infinite surface, to one side only

$$\text{lumens} = \text{apparent candles (of whole surface) at 1 ft.} \tag{22}$$

The latter simply means as before, that they are merely equal numerically.

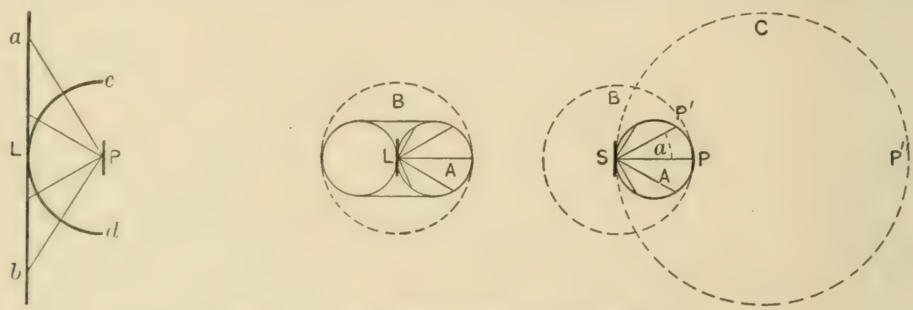
It will be seen therefore that the flux for the same candle-power is very different, depending upon whether the source is a point, line or surface. At a distance of 1 foot the same flux radiat-

ing from a foot of an infinitely long line, will give twice the candle-power, and from a square foot of an infinite surface, 4π times the candle-power that it would when issuing from a point. The resultant radiations may be conceived as shown in the diagrams. From a point P, Fig. 1, they issue like an expanding sphere; from any part of an infinite line L, Fig. 2, like an expanding cylinder; and from any part of an infinite surface S, Fig. 3, like an advancing plane.



Figs. 1, 2 and 3.—Radiations from a point, an infinite line, and an infinite surface.

In practice, however, sources are neither points, nor infinite lines nor infinite surfaces. Most artificial lamps however may generally be treated as a point without appreciable error, if placed far enough from the photometer screen or from the surface which is to be illuminated. An infinitely long line L, Fig. 4, can be shown to be equivalent in its apparent candle-power, that is, in the illumination it produces on a small surface P, to a finite portion *a b* of that source bent into a semi-circle *c d* around the point P as a center. And an infinite surface like the



Figs. 4, 5 and 6.—Finite lines and surfaces.

sky can similarly be shown to be equivalent in the same sense to a finite portion of that surface bent into a hemisphere around the point, as shown in the same figure if the line represents the large surface and the semicircle represents the hemisphere. Hence these imaginary mathematical conceptions can in practice often be reduced to finite and real quantities.

Let us now consider a finite length of line and extent of surface and see how they differ from point sources. If L, Fig. 5, is a short line it can be shown that from the so-called cosine law, the polar diagram will be a tangent circle A, that is, the chords of this circle will represent the candle-power in those respective directions.[1] The diameter is the candle-power usually stated, namely, that taken perpendicularly to the line at its center. If this tangent circle be revolved around the line as an axis, a ring shaped solid will be formed called a torus, the surface of which is the polar diagram in space. If this line were a point source, the polar diagram would be the large dotted circle B, as the intensities are then the same in all directions; the polar diagram of space will then be a sphere around the point as a center. It can be shown that the total flux due to this peculiar distribution of candle-power from the line is as follows when the candle-power represents the one taken perpendicularly as usual:

$$\text{lumens} = \text{apparent candles} \times \pi^2 \text{ (approximately 9.87)} \quad (23)$$

$$\text{spherical candles} = \text{apparent candles} \times \pi \div 4 \text{ (approx. 0.785)} \quad (23a)$$

When the length is not very short the lamp should be placed at a greater distance from the photometer, so that it is apparently short as far as the photometer measurement is concerned.

For a small infinite surface S, Fig. 6, it can be shown that the polar diagram in the plane of the paper will again be the same tangent circle A, but the diagram in space will now be a sphere generated by revolving this circle on its diameter PS. And if the light passes out from only one side, as usual from actual surfaces, there will be only one such sphere. The total flux in terms of the candle-power measured perpendicularly as usual can now be shown to be:

$$\text{lumens} = \text{apparent candles} \times \pi \quad (24)$$

or

$$\text{spherical candles} = \tfrac{1}{4} \text{ apparent candles.} \quad (25)$$

This is an important result leading to very useful deductions,

[1] As the source is here considered to be a mere line, there is no light issuing from its ends. If a tube has no opaque caps over its ends, the light from the ends must of course be added.

as will be shown later. The surface referred to should be small or at least far enough removed from the photometer to be considered so. If the source were a point of the same candle-power, the candle-power diagram in space would be the larger sphere B around S as a center. Or if the flux is the same for the surface as for the point source, the polar diagram for the surface will be the very large sphere C and the perpendicular candle-power will then be four times as great. Hence a surface may be considered to be somewhat like a reflector, as it condenses all the flux and sends it out in one general direction, thereby greatly increasing its density, (or its candle-power as it is more generally called), in that direction.

There is another measure used in many text books and included in those officially determined upon in the Geneva Congress of 1896, called the "brightness of the source", in this country usually measured in "candles per square inch." The writer has shown in an article published elsewhere[1] that to use this as a unit is unnecessary; it causes confusion owing to a different or loose use of the term candle-power, and it is really a unit of precisely the same kind as illumination when measured in foot-candles; it may therefore always be expressed in foot-candles; the difference between the two may be said to be analogous to the difference between a cubic yard and a gallon, both of which measure the same physical quantity, namely, volume, and therefore might be expressed in terms of the same unit. It is not necessary to repeat the arguments or demonstration here. In the system employed in this paper, this unit will not be used as a unit, because most calculations are simpler without using it. It may be, and actually is, a convenient expression to use at times but it creates confusion unless it is clearly understood that the term candle-power involved in that unit does not mean the same thing as the one involved in the general use of that term, but that it really expresses a flux and not a flux density. It can be shown that numerical values expressed in terms of this unit can be reduced to the more common unit, foot-candles, by the following formula:—

$$\text{foot-candles} = \frac{\text{candles per sq.in.} \times 144}{1/\pi} = 452 \times \text{candles per sq. in.} \qquad (26)$$

[1] *Electrical World*, Sept. 26, 1908, p. 673.

There is an interesting relation, which may at times be quite useful, which follows from the above formula, namely, the candle-power equivalent of a foot-candle of reflected illumination. It follows from the above mentioned equivalent that an illumination of any foot-candles over a given surface can always be expressed in equivalent or apparent candle-powers, and that this relation can be determined by calculation, assuming for this purpose that the surface which is illuminated reflects perfectly, that is, absorbs no light. It can be shown in this way that every square foot of surface illuminated to the amount of one foot-candle, will, if measured on a photometer, perpendicularly to the surface, have an apparent candle power of $1/\pi$, that is 0.3183, or about 1/3 candle. Hence the apparent reflected candle-power of an illuminated surface, or of an origianl source of light in the form of a surface, can be calculated from the illumination by the following formula:

$$\text{apparent candles} = \text{foot-candles} \times \text{sq. ft.} \times 0.3183. \quad (27)$$

This formula is often of use, but it must be distinctly understood that this is merely an equivalent or apparent candle-power which will produce the same illumination of the screen on which it is measured, as a lamp of that many candles would produce; it is an equivalent in no other sense and it would not be proper to calculate the flux from this candle-power as though it were a point source, nor the illuminations in other than this one direction, as the equivalency does not extend any further. It is a candle-power of a flat surface and not of a point; hence it follows the laws of a surface and not those of a point; these laws were described above. The use of the above formulas in practice will be illustrated below by numerical examples.

The apparent candle-power of an illuminated surface affords a simple means of determining the absorption of any surface, such as of the walls of a room. Illuminate a known surface of it, say a round disc 1 sq. ft. in area, (therefore about 13½ inches in diameter, which may be screened off with a black cloth) with a known candle-power at a known distance and calculate the illumination in foot-candles; this multiplied by 0.3183, (roughly ⅓), is the value of candle-power that would be photometered, if it were perfect and did not absorb any of the light; then measure its actual apparent candle-power and

the difference, or the ratio, will give the loss by absorption. As the apparent candle-power of a square foot of surface illuminated to one foot-candle is very small, the illumination of the disc should be as bright as possible and the photometer should be adapted for measuring very low candle-powers. This test, of course, is only a rough and ready one, although in the laboratory, with suitable facilities, it might be carried out to some precision.

There is a useful law which has been referred to above, called the cosine or Lambert's law (discovered in 1760). It refers to flat surfaces which either reflect, transmit, or emit diffused light in all directions in the hemisphere surrounding them. It applies only when the light comes from the surface alone and not from the interior also, and it therefore does not apply to a gas flame, or to the light from a vacuum tube, both of which are transparent. This law leads to some important deductions. It is, however, not always strictly correct, especially when the angles with the surfaces are small, and the errors are not the same for all materials; it is probably sufficiently accurate for the purposes of the illuminating engineer, most of whose calculations do not permit of, nor do they require great accuracy.

Referring to Fig. 6, this law is that the apparent candle-power of the light from a surface S, seen from points P, P′, diminishes with the cosine of the angle a with the normal. Thus if the light from the flat surface S, measures n candles from P, then it will be $n \cos a$ candles from a point P′ at an angle a. As was shown above, this law enables one to determine certain differences between a point source of light and a flat source, that is, between directed light and diffused light, which are often of use. It can be shown by the cosine law that when light issues from the whole of one side of a small, flat, uniformly bright surface S in Fig. 6, the intensity varies in such a way that the usual polar diagram of the source will be a tangent circle A as illustrated, representing a sphere, the diameter of which is the normal intensity S P. Hence if S P represents the candle-power as measured by the photometer, and a sphere be drawn on S P as a diameter, then the lengths of the other lines radiating from S to the sphere, represent the intensities in those respective directions.

There is a very useful deduction from the cosine law. If a uniformly bright surface S, Fig. 7, is looked at or photometered from any point P, through a definite opening O in an opaque screen, then the light reaching P is found to be independent of the inclination of the surface S with the axis of the beam, as S′ for instance, or of its distance from the point P or from the opening O, as S″ for instance, provided only that the surface is always large enough to completely cover the field seen from P through O, that is, provided the opening seen from P is always completely filled with light. Hence the light from the opening, measured at P, will be constant depending only on the brightness but not the extent or distance of the surface S.

From this it follows that the intensity measured at P would also be the same if the flat source be brought quite up to the opening; hence such a measurement really gives the light from an

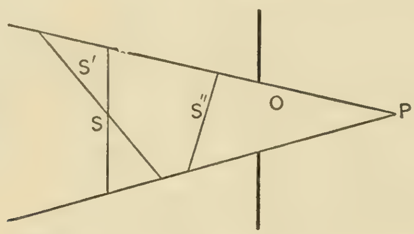


Fig. 7.—Light from a bright surface.

equal area of the original source. Therefore, to measure the light given off per square inch of surface, be the surface a direct source of light like heated metal, or indirect like a white wall, or indefinite like a cloud, or the sky, etc., and be it near or far, inclined or not, accessible or inaccessible, make a hole, say of 1 sq. in., in a screen and measure the candle-power of the light coming through this hole with a photometer in the usual way as though the hole were the source, being sure that each part of the hole has light giving surface behind it. The candle-power thus measured, is equal to that of one square inch of the source itself. Even if the original surface was inclined to the beam at any unknown angle, or very rough and irregular like a cloud, this measurement gives directly the density of the radiation, that is, the apparent candle-power of one square inch of the source normal to the surface. It is important to remember, however, that the candle-power thus obtained applies only to the direction normal to the surface of the hole and to no other

direction, in which respect it differs from a point source, as shown above; hence the term "apparent" candle-power. The same method is used in radiation pyrometers, as the same reasoning applies to heat radiation. Of course, such losses as those due to absorption, dispersion, particles of dust or vapor, etc., are not considered here; for great distances they might be quite large.

The illumination produced by the light from such a small illuminated opening, normally to it, will be inversely proportional to the square of the distance from the opening to the point P, because the light from the opening is like that from an equal area of the original source, which can be conceived to be made up of points of light, the light from each of which is inversely proportional to the distance from it to the point P; hence the light from all of them together also follows this law. In general, such an opening may be treated precisely like a corresponding illuminated surface of equal area, as it has all of the properties and follows all the laws of such a surface; it differs from a point of light precisely as an illuminated surface does. Hence the flux from it will be only one-fourth of that of a point source of the same candle-power.

It will be noticed that none of the above formulas is based on any empirical constants, that is, on any numbers that have to be obtained from experiments. The formulas are theoretically correct and exact, being based entirely on the laws of the radiation and reflection of light. Any inaccuracies in applying them to practical problems are due to the fact that one can never realize the theoretically perfect conditions of true points, lines and surfaces. Fortunately, the inaccuracies in practice are generally where they are of least consequence.

EXAMPLES.

The following numerical examples will show some of the applications to practical cases, of the formulas deduced above.

Whenever any source of light, whether direct or indirect, giving either diffused or directed light, can have its mean candle-power measured in *all* directions by a photometer, it is generally the simplest and best plan thus to measure it. This remark applies to all sources which are small enough or can be moved off far enough from the photometer to be considered virtually

a point, and which are adapted to be revolved or measured with some form of integrating photometer or by any other means so as to get the average light in all directions. It applies also to tubular lamps or to flat surfaces, either original or secondary sources, or radiating from one side only, provided only that the mean candle-power in *all* directions can be measured. If the light issues only to one side, as from a flat opaque surface, it would suffice to measure the mean intensity in all directions to one side only, that is, in one hemisphere, being careful to remember that the flux is then only the hemispherical radiation and not the spherical. The number obtained for such a hemispherical mean candle-power must be divided by 2 to calculate the flux in spherical candles or lumens, for if the same quantity of radiation be distributed in all directions instead of only through a hemisphere, the mean candle-power of such a source would be only half as great.

Having measured the mean candle-power in all directions—say it is 5 candles—the calculations from it are very simple. The candle-powers in any specific directions are obtained by direct measurement, and the illumination produced at specific distances in those directions are calculated from these candle-powers in the usual way, by means of formula (6) which is too well known to require illustrating. The total flux in spherical candles is, according to formula (7), simply 5; in lumens, it is, according to formula (8),

$$\text{lumens} = 5 \times 4\pi = 62.5.$$

The mean brightness or flux density of the source itself in any particular direction, if it can be considered a point, is simply expressed by the candle-power in that direction; there is no other way of expressing it. If the source is a surface, this brightness or flux density can be expressed in illumination units; it depends on the area of the light-emitting surface of the source. If it is a white, ground glass, phosphorescent or incandescent surface radiating diffused light, and if it has a surface of say 10 sq. in., the flux density at this surface calculated from the lumens, will be from formula (16).

$$\text{flux density} = \frac{62.5 \text{ lumens}}{(10 \div 144) \text{ sq. ft.}} = 900 \text{ foot-candles,}$$

or calculated from the spherical candles by means of formula (15)

$$\text{flux density} = \frac{4\pi \times 5 \text{ spherical candles}}{(10 \div 144) \text{ sq. ft.}} = 900 \text{ foot-candles.}$$

Or if it is a lamp filament say 6 inches long and 0.003 inch in diameter, its surface will be 0.0004 sq. ft. and the flux density on the filament, from the same formulas, will be 156,000 foot-candles. If it is reflected or transmitted light, and if the original flux radiated on to the surface, is, say, 125 lumens, the efficiency of the reflection or transmission is 62.5÷125=50%. If the lamp consumed 21 watts, its specific output in spherical candles per watt will be 5÷21=.24, or in lumens per watt, it will be 62.5÷21=3. Thus all the data that one needs can be deduced when the true *mean* candle-power can be measured.

When the mean candle-power in *all* directions cannot be measured, which is often the case, other methods may be used to determine some other quantity from which the necessary data can be calculated. They are best considered under the following special cases.

If a lamp, Fig. 8, with a reflector R behind it throws out a conical beam of light, like a locomotive or trolley head-lamp,

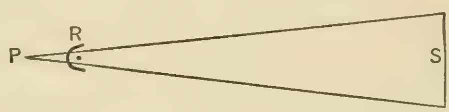


Fig. 8.—Light from lamp with reflector.

and if the beam has a cross-secton S of 5 sq. ft. at a distance of 10 ft., and if the average candle-power measured in that beam is 1000 c.p., then according to formula (10)

$$\text{lumens} = \frac{1000 \text{ c. p.} \times 5 \text{ sq. ft.}}{10 \text{ ft. squared}} = 50$$

or according to formula (9)

$$\text{spherical candles} = \frac{1000 \text{ c. p.} \times 5 \text{ sq. ft.}}{4\pi \times 10 \text{ ft. squared}} = 4.$$

This means that the flux of light is exactly the same in amount as it would be from a bare lamp whose mean candle-power in all directions is 4 c.p. therefore having a flux of 4 spherical c.p.,

only that the flux of light in the former case has all been concentrated into a small beam.

If the diameter of the reflector is say 12 inches, the light emitting area at the front of the lamp will be about 0.8 sq. ft., hence the flux density (or illumination) of the light where it issues from the lamp is according to formula (16)

$$\text{flux density} = \frac{50 \text{ lumens}}{0.8 \text{ sq. ft.}} = 63 \text{ foot-candles}$$

or from formula (15)

$$\text{flux density} = \frac{4\pi \times 4 \text{ sp. candle}}{0.8 \text{ sq. ft.}} = 63 \text{ foot-candles.}$$

The flux radiated from the front of this lamp, is therefore, the same as that from a flat surface 12 inches in diameter whose illumination is 63 foot-candles. It radiates directed light, however, and not diffused light, hence the similarity does not extend to the candle-power.

When the beam from such a search lamp is nearly parallel, or the reflector is large, the distance from the measured cross-section S, Fig. 8, to the lamp, must not be measured to the lamp itself, but to the point P behind the lamp where the point of the conical beam would be if the beam were continued backwards. This correction will be small for most of the calculations occurring in commercial practice with rapidly diverging beams or when the distance is relatively great; for search-lamp beams however, it becomes important. In such cases (except for an absolutely parallel beam) the correct distance can be calculated by dividing the diameter of the beam at the measured cross-section, by the difference between it and the diameter of the beam at the front of the lamp, and multiplying by the distance from the cross-section to the front of the lamp (all in feet); the result will be the true distance S P.

If the beam is perfectly parallel, it can no longer be treated as a conical beam; its candle-power cannot be measured directly, as there is then no such thing as the "distance to the source." But the reading of the photometer placed in the beam at any particular section of it, gives the foot-candles of illumination, by dividing the candle-power of the standard lamp by the square of its distance in feet from the photometer screen; this gives the "illumination" or flux density of the search-lamp beam at that

section, in foot-candles. Then it is quite correct to say that at this section the beam is *equivalent* to so-and-so many candles at such-and-such a distance, some convenient distance, such as 10 ft. for instance, being chosen. Hence if the beam measured 63 foot-candles it is equivalent in candle-power (but not in flux) to 6300 candles at 10 ft. It would be meaningless to state such an equivalent candle-power without stating the assumed distance also, although such statements are sometimes made. If by such an unmentioned distance is meant the distance to the search-lamp itself, then the generally enormous candle-power obtained simply means, like in the above case of 6300 candles, that this many candles placed where the reflector is, would be required without a reflector to produce the same illumination at the place at which it was measured; but it does not mean that the flux of light of this beam is equivalent to that which this many candles would radiate if burning openly. In giving such an *equivalent* in candle-powers in such a case, it must therefore be clearly understood that it is an equivalent only as far as the illumination at that place is concerned. It is quite correct to say that a distant object on which this beam falls is illuminated as brightly as it would be by 6300 candles at a distance of 10 ft. from that object.

Some further deductions can be obtained from the flux which is calculated from this same measurement in foot-candle and from the cross-section of the beam in square feet. Let the latter be 0.8 sq. ft. then the flux is, from formula (16)

$$\text{lumens} = 63 \text{ foot-candles} \times 0.8 \text{ sq. ft.} = 50$$

or from formula (15)

$$\text{spherical candles} = 63 \text{ foot-candles} \times 0.8 \text{ sq. ft.} \div 4\pi = 4.$$

Such a beam would be best specified by stating that it radiated a flux of 50 lumens (or 4 spherical candles) through a cross-section of 0.8 sq. ft. therefore having a flux density of 63 foot-candles.

There is another way of stating the equivalency of such a beam in candle-powers, which though of little importance in this case, may be quite useful in other cases. The flux in spherical candles, namely, 4, in this case, shows from formula (7) that the flux of this beam is equal to that of a small lamp having a mean value of only 4 c.p. in all directions. The

same result is obtained from formula (8) for lumens but the calculation is not so simple.

The following example refers to light emitting surfaces. If a square inch of a phosphorescent surface photometered perpendicularly gives $\frac{1}{2}$ c.p., then the amount of flux issuing from that surface in all directions to one side of it, is, according to formula (25), $\frac{1}{4} \times \frac{1}{2} = \frac{1}{8}$ spherical candles; that is, it gives as much flux as a lamp which photometers $\frac{1}{8}$ c.p. in all directions or has a mean candle-power of $\frac{1}{8}$. In lumens the flux would be according to formula (24)

$$\text{lumens} = \pi \times \text{candle-power} = \pi/2 = 1.57.$$

The flux density (or illumination) of this surface in foot-candles, is the flux per square foot, that is, the flux divided by the area in square feet; one square inch is 1/144 sq. ft., hence from formula (15) for spherical candles

$$\text{flux density} = \frac{4\pi \times \frac{1}{8}}{1/144} = 226 \text{ foot-candles}$$

or from formula (16) for lumens

$$\text{flux density} = \frac{1.57}{1/144} = 226 \text{ foot-candles.}$$

This result means that the square inch gives off as much diffused light as a white surface of 1 sq. in. would if placed at one foot from a lamp of 226 candles, if the reflection were perfect—that is, if there were no absorption. It must be remembered that this remark applies to small surfaces only, or to those far enough to be considered small. If it is desired to express the reflected illumination in terms of the unit "candles per square inch" no formula is required, because the original data give it in these terms, namely, $\frac{1}{2}$ c.p. from 1 sq. in., but as a check of the above result, and to illustrate the use of formula (26), it can be calculated from the foot-candles as follows:

$$\text{candles per sq. in.} = \frac{\text{foot-candles}}{452} = \frac{226}{452} = \frac{1}{2}.$$

The candle-power of a square centimeter of platinum at its melting point is given as about 20, or about 130 c.p. per sq. in. From formula (26) the flux density equals $130 \times 452 =$ 58,760 foot-candles. The flux radiated from 1 sq. in. according to formula (24) in lumens is candles $\times \pi = 130 \times 3.14 = 408$; or

in spherical candles from formula (25) it is 130 candles$\div$4=32.5. These two results can be checked with each other by means of formulas (13) or (14) which show that 32.5 spherical candles are equal to 408 lumens. The above flux density might also have been calculated with formulas (15) and (16) from the flux and the surface, and the same result would have been obtained. In general, any of the formulas must lead to the same result as all of them are based on the same uniform system.

Daylight is given in Ganot's Physics as "180 candles per square yard." Assuming this to mean that an opening of 1 sq. yd. exposed to daylight would, if measured by a photometer at a sufficiently great distance to be considered a point, correspond to 180 candles placed where the opening was, then all of the other data can be calculated. The light equals 20 candles per sq. ft., hence the corresponding illumination, or flux density, from formula (27), is $20\div(1\times0.3183)=63$ foot-candles. Or from formula (26) the same result is obtained, though less directly. This result means that according to the data, a window at daylight sheds as much light into a room as a white surface of the same area which gives off a reflected illumination of 63 foot-candles. The total flux for a square foot is found from formula (24) to be candles$\times\pi=20\times3.14=63$ lumens, or from (25) 5 spherical candles. Hence for a window of one square yard it would be 9 times this, namely, 576 lumens or 45 spherical candles. From this result it is easy to ascertain how many lamps to use at night in order to radiate the same amount of light in that room. A single lamp having a mean candle-power of 45, or about 3 of 16 candles, radiate a flux of about 45 spherical candles and are therefore sufficient. This conclusion is shown by formula (7) which is too simple to deserve that name. When the flux is in lumens however, the calculation is not so simple; formula (8) then gives the result—which, of course, is the same.

The above example illustrates the error which can easily be made if one does not distinguish between the light from a point and that from a surface. The light from a surface of one square yard is stated to be 180 candles, but lamps (point sources) of 180 candles in that room would be far more than are necessary. As was shown above, for the same flux the candle-power equiva-

lent of a surface is 4 times that of a free lamp, hence only $\frac{1}{4}$ of $180 = 45$ candles are required (as was shown above). It would also be a grave error to multiply the apparent candle-power of the light from the window namely, 180 candles, by 4π (that is, $12\frac{1}{2}$) to get the flux in lumens, as it is only $\frac{1}{4}$ of this value. If the inside surfaces of such a room were 1000 sq. ft., then the mean illumination by 567 lumens or 45 spherical candles, would be, from either formulas (16) and (15) 0.567 foot-candles.

If the specific consumption of each lamp is 3 watts per candle, which of course means spherical candles of flux, then, the total consumption will be $3 \times 45 = 135$ watts; with energy at 10 cents per kilowatt hour, the cost would be 1.35 cents per hour; this is, therefore, the money value of the daylight in that room.

If the photometric value for daylight is not known it can be measured by cutting a hole in a black opaque screen, say of 1 sq. ft., in the form of a circular disc which will then be about $13\frac{1}{2}$ inches in diameter. Expose this opening to daylight at the place and in the direction in which it is to be photometered. The square foot can be considered to be an average square foot of the sky, clouds, trees, buildings, etc., which reflect the daylight into the window. Photometer this opening as though it were a lamp and if the above value from Ganot's Physics is correct, it will be found to be about 20 candles, although of course it will vary greatly at different times and places. All the rest of the deductions are then made as described above.

Suppose it is desired to illuminate a room having an inside surface of 1000 sq. ft. to an average of 2 ft. candles. According to formulas (16) and (15), the total flux required will be $1000 \times 2 = 2000$ lumens, or $1000 \times 2 \div 4\pi = 160$ spherical candles. The latter figure shows directly that about 10 lamps of 16 mean candles will give the desired flux. The same figure can be obtained less directly from the lumens by means of formula (8). This value of course refers only to the direct light from the lamps; the walls and ceiling will also illuminate each other, hence somewhat less than the above value of candle-power will suffice; this correction is described in text books and need not be explained here.

Suppose it is desired to measure approximately the absorption of light by a wall or ceiling. Screen off a known area of it with a black screen, say a round area of 1 sq. ft. (13½ inches diameter); illuminate it as brightly as possible with a known candle-power, say 100 candles at known distance, say 5 ft. Then the illumination which falls on the surface is, according to the well known formula (6) $100 \div 5^2 = 4$ foot-candles; hence if it were a perfect matt reflector, it would have an apparent candle-power, according to formula (27) of $4 \times .3183 = 1.3$ candles. Measure the light with a photometer which must be adapted to very small candle-powers, and the distance from the wall must not be too small if the area is as large as 1 sq. ft. Suppose this measurement gave 0.8 candles, then the loss by absorption is $1.3 - 0.8 = 0.5$, which is about 38% of the original. The flux reflected back by such a wall will therefore be about $100 - 38 = 62\%$ of that which falls on it. An actual measurement recently made at the Bureau of Standards showed the apparent candle power per square foot, per foot-candle of illumination, falling on an unusually good white matt surface of ground milk glass, to be 0.27 candles. If theoretically perfect the value should have been 0.3183, hence the absorption was about 15%.

In all of the above examples which refer to surfaces, it must be remembered that when use is made of the apparent candle-power of a surface, this surface must be relatively small, or sufficiently far from the photometer to be considered so. The equivalent candle-power of a whole wall or a large window, for instance, would of course be greater than that from 1 sq. ft. of it, nor would it always be equal to the latter multiplied by the number of square feet, unless the photometer is very far off. The per square foot value is used merely as a convenient number from which other things, such as the flux, can be easily calculated. It would be a grave error to say that if one square foot of a wall of a room photometers, say a ½ candle, and if there are 1000 sq. ft., there would be an equivalent of 500 candles in that room, in the usual sense. All of the calculations from surface sources (reflecting walls, windows, etc.) to equivalent point sources (lamps) or the reverse should be made by first ascertaining the value of the flux, from which it is then very easy to transfer to either surfaces or points.

In making photometric calculations of surfaces, such as the walls of a room which are too large to be considered as points and too small to be considered as infinitely large, difficulties sometimes arise concerning the apparent candle-power and hence the illumination of an object by these walls, but not concerning the flux. The flux issuing from such surfaces is of course the same per square foot no matter how large or small, as it depends only on the illumination (flux density) issuing from it, as calculated from formulas (15) or (16). Moreover, the flux is independent of whether the light is directed or diffused, or how it is diffused, that is, no matter what directions the rays may have after leaving, as long as they all pass through this same area and therefore have the same flux density. For a room, however, an approximation of the average candle-power value or reflecting value of the walls on an object in the room, may be obtained as follows. It was shown above that the illumination in foot-candles falling on a surface, say a table, book, etc., from an infinitely large luminous surface, such as the sky, is the same as the foot-candles (or flux density) issuing from that large surface itself. Also that an infinitely large surface is equivalent to a hemisphere of the same surface around the table, book, etc., as a center. Now any half of such a room may be considered to be approximately such a hemisphere. Hence a book or table in the middle of a room will receive from those walls an illumination in foot-candles equal to the average foot-candles (flux density) issuing from the walls which form this hemisphere around it. Hence if the walls send out an "illumination" of an average of say 2 foot-candles, then a book or table illuminated thereby will receive 2 foot-candles. This value of course refers to light from the walls only, as for instance in the case of concealed lamps or indirect lighting; any direct light from free lamps that may be in the room, or that of daylight from a window, must of course be added to this value.

The above conclusion also affords a convenient method of measuring the average "illumination" issuing from the walls of a room. Place a photometer screen in the middle of the room facing the half of the room which is to be photometered. It must be completely exposed on one side and must have no edges, mirrors, or other obstructions, as it must receive the light from

the whole hemisphere. Photometer this as usual, with a known light on the other side, and from the candle-power and distance (in feet) of the lamp calculate the illumination in foot-candles; this value will then be the average reflected from the walls of that hemisphere.

It may sometimes be of interest to know the amount of flux of daylight, sunlight, moonlight, light in fog, etc. The writer has no data and the information he has found in books is indefinite as to its meaning. But the value may easily be calculated from a simple measurement. Expose one side of a photometer screen to the light and thereby obtain the so-called illumination (really the flux density) in foot-candles. Then according to formula (16) the lumens of flux in such a beam will be equal to the foot-candles multiplied by the cross-section of the beam; that is, the number of foot-candles is the same as the number of lumens per square foot, because foot-candles are in fact flux densities. Formula (15) gives this result in spherical candles instead of lumens. If the above figure for daylight given in Ganot's Physics (180 c.p. per. sq. yd.) is correct and if the above interpretation of it is correct, then such a photometer test would show an illumination of about 63 foot-candles. Hence the flux in every 1 sq. ft. of such a beam is about 63 lumens or 5 spherical candles, as was calculated above. If the cost of energy for artificial electric lighting is 10 cents per kw. hour, and the lamps require 3 watts per spherical candle, the cost of 5 spherical candles will be $3 \times 5 \times 10 \div 1000 = 0.15$ cents or 1½ mills per hour. Hence the money value of the daylight (based on the cost of replacing it) is about 1/7 of a cent each hour per square foot of cross-section of the beam. This result ought to induce us to appreciate the great money value of this free gift of nature. Architects and decorators should consider this result in designing windows and light-reflecting interior decorations.

In conclusion the writer wishes to repeat that many of the above calculations of light are necessarily only approximate, as the exact conditions are never fulfilled. However, they are probably sufficiently approximate for the purposes of the illuminating engineer, most of whose calculations concerning illumination do not permit of, nor do they require, great accuracy.

APPENDIX.

In the following table all the above formulas together with some others to make the set complete, have been reduced to their simplest forms, and arranged conveniently for rapid reference; they have also been properly classified to avoid mistakes in selecting the proper one for any particular case. The reference numbers show where they are described in the text.

For all sources (points, lines or surfaces):

1 lumen = 0.0796 spherical candles (12)

lumens = 12.6 × spherical candles (13)

lumens = foot-candles × sq. ft. (16)

1 spherical candle = 12.6 lumens (11)

spherical candles = 0.0796 × lumens (14)

spherical candles = 0.0796 × foot-candles × sq. ft. (15)

$$\text{foot-candles} = \frac{\text{lumens}}{\text{sq. feet}} \qquad (16)$$

$$\text{foot-candles} = 12.6\frac{\text{spherical candles}}{\text{square feet}} \qquad (15)$$

$$\text{square feet} = \frac{\text{lumens}}{\text{foot-candles}} \qquad (16)$$

$$\text{square feet} = 12.6\ \frac{\text{spherical candles}}{\text{foot-candles}} \qquad (15)$$

Solid angle:

1 absolute unit = 0.0796 sphere units

absolute units = 12.6 × sphere units

$$\text{absolute units} = \frac{\text{sq. feet}}{\text{feet}^2} \qquad (4)$$

1 sphere unit = 12.6 absolute units

sphere units = 0.0796 × absolute units

$$\text{sphere units} = 0.0796\ \frac{\text{sq. feet}}{\text{feet}^2} \qquad (4)$$

For point sources only:

$$\text{lumens} = \frac{\text{candles} \times \text{sq. feet}}{\text{feet}^2} \qquad (10)$$

lumens = cp. × absolute units solid angle (2)

lumens = 12.6 × (mean) candles (only for whole
sphere) (8), (20)

lumens = ft.-cand. × feet^2 × abs. units solid angle

lumens $= 12.6 \times$ foot-candles $\times$ feet^2 (only for whole sphere)

spherical candles $= 0.0796 \dfrac{\text{candles} \times \text{sq. ft.}}{\text{feet}^2}$ (9)

spherical candles $=$ cp. $\times$ sphere units (2)

spherical candles $=$ (mean) candles (only for whole sphere) (7)

spherical candles $=$ ft.-cand. $\times$ feet^2 $\times$ sphere units

spherical candles $=$ foot-candles $\times$ feet^2 (only for whole sphere)

candles $=$ foot-candles $\times$ feet^2 (6)

candles $= \dfrac{\text{lumens} \times \text{feet}^2}{\text{sq. feet}}$ (10)

candles $= 12.6 \dfrac{\text{spherical candles} \times \text{feet}^2}{\text{square feet}}$ (9)

candles $=$ lumens $\div$ absolute units solid angle (2)

candles (mean) $= 0.0796 \times$ lumens (only for whole sphere) (8), (20)

candles $=$ spherical candles $\div$ sphere units (2)

candles (mean) $=$ spherical candles (only for whole sphere) (7)

foot-candles $= \dfrac{\text{candles}}{\text{feet}^2}$ (6)

foot-candles $= \dfrac{\text{lumens}}{\text{feet}^2 \times \text{absolute units solid angle}}$

foot-candles $= 0.0796 \dfrac{\text{lumens}}{\text{feet}^2}$ (only for whole sphere) (17)

foot-candles $= \dfrac{\text{spherical candles}}{\text{feet}^2 \times \text{sphere units}}$

foot-candles $= \dfrac{\text{spherical candles}}{\text{feet}^2}$ (only for whole sphere)

square feet $= \dfrac{\text{lumens} \times \text{feet}^2}{\text{candles}}$ (10)

square feet $= 12.6 \dfrac{\text{spherical candles} \times \text{feet}^2}{\text{candles}}$ (9)

feet^2 $= \dfrac{\text{candles} \times \text{square feet}}{\text{lumens}}$ (10)

feet^2 $= 0.0796 \dfrac{\text{candles} \times \text{square feet}}{\text{spherical candles}}$ (9)

$$\text{feet}^2 = \frac{\text{candles}}{\text{foot-candles}} \tag{6}$$

$$\text{feet}^2 = \frac{\text{lumens}}{\text{ft.-cand.} \times \text{absolute units solid angle}}$$

$$\text{feet}^2 = 0.0796 \frac{\text{lumens}}{\text{foot-candles}} \text{ (only for whole sphere)}$$

$$\text{feet}^2 = \frac{\text{spherical candles}}{\text{ft.-cand.} \times \text{sphere units}}$$

$$\text{feet}^2 = \frac{\text{spherical candles}}{\text{foot-candles}} \text{ (only for whole sphere)}$$

$$\text{absolute units solid angle} = \text{lumens} \div \text{cp.} \tag{2}$$

$$\text{absolute units solid angle} = \frac{\text{lumens}}{\text{ft.-cand.} \times \text{feet}^2}$$

$$\text{sphere units} = \text{spherical candles} \div \text{cp.} \tag{2}$$

$$\text{sphere units} = \frac{\text{spherical candles}}{\text{ft.-cand.} \times \text{feet}^2}$$

For infinite straight line sources only:

("Ap. cp." here always refers to the apparent candle-power of the whole infinite line at the respective distances; "per foot" refers to one foot of the source, and "feet" refer to the perpendicular distances from the source. "Foot-candles" refer to the flux density (or illumination) of the beam at the respective distances.)

$$\text{lumens per foot} = 6.28 \frac{\text{ap. cp.}}{\text{feet}} \tag{21}$$

$$\text{lumens per foot} = 6.28 \times \text{foot-candles} \times \text{feet} \tag{18}$$

$$\text{spherical candles per foot} = 0.5 \frac{\text{ap. cp.}}{\text{feet}}$$

$$\text{spherical candles per foot} = 0.5 \times \text{foot-candles} \times \text{feet}$$

$$\text{apparent candles} = 0.159 \times \text{lumens per foot} \times \text{feet} \tag{21}$$

$$\text{apparent candles} = 2 \times \text{spherical candles per foot} \times \text{feet}$$

$$\text{apparent candles} = \text{foot-candles} \times \text{feet}^2$$

$$\text{foot-candles} = 0.159 \frac{\text{lumens per foot}}{\text{feet}} \tag{18}$$

$$\text{foot-candles} = 2 \frac{\text{spherical candles per foot}}{\text{feet}}$$

$$\text{foot-candles} = \frac{\text{ap. cp.}}{\text{feet}^2}$$

$$\text{feet} = 0.159 \frac{\text{lumens per foot}}{\text{foot-candles}} \tag{18}$$

$$\text{feet} = 2 \frac{\text{spherical candles per foot}}{\text{foot-candles}}$$

$$\text{feet} = 6.28 \frac{\text{ap. cp.}}{\text{lumens per foot}} \tag{21}$$

$$\text{feet} = 0.5 \frac{\text{ap. cp.}}{\text{spherical candles per foot}}$$

$$\text{feet}^2 = \frac{\text{ap. cp.}}{\text{foot-candles}}$$

For short straight line sources only, and only for relatively long distances:

("Apparent candles" here refers only to those perpendicular to the line at any distance. "Foot-candles" refer to the flux densities (or illumination) of the beam at the respective distances.)

$$\text{lumens} = 9.87 \times \text{apparent candles} \tag{23}$$
$$\text{lumens} = 9.87 \times \text{foot-candles} \times \text{feet}^2$$
$$\text{spherical candles} = 0.785 \times \text{apparent candles} \tag{23a}$$
$$\text{spherical candles} = 0.785 \times \text{foot-candles} \times \text{feet}^2$$
$$\text{apparent candles} = 0.101 \times \text{lumens} \tag{23}$$
$$\text{apparent candles} = 1.27 \times \text{spherical candles} \tag{23a}$$
$$\text{apparent candles} = \text{foot-candles} \times \text{feet}^2$$

$$\text{foot-candles} = \frac{\text{apparent candles}}{\text{feet}^2}$$

$$\text{foot-candles} = 0.101 \frac{\text{lumens}}{\text{feet}^2}$$

$$\text{foot-candles} = 1.27 \frac{\text{spherical candles}}{\text{feet}^2}$$

$$\text{feet}^2 = \frac{\text{apparent candles}}{\text{foot-candles}}$$

$$\text{feet}^2 = 0.101 \frac{\text{lumens}}{\text{foot-candles}}$$

$$\text{feet}^2 = 1.27 \frac{\text{spherical candles}}{\text{foot-candles}}$$

For infinite flat surface sources only:

("Ap. cp." here always refers to the apparent candle-power of the whole infinite surface at one foot distance. The rays are

all parallel, hence the flux density (or illumination) is the same for all distances, and applies to either the source or the beam. The flux refers to that on one side only).

lumens per square foot = ap. cp. at 1 foot (22)
lumens per square foot = foot-candles (19)
spherical candles per square foot = 0.0796 × ap. cp. at 1 ft.
spherical candles per square foot = 0.0796 × foot-candles
apparent candles at 1 foot = lumens per square foot (22)
apparent candles at 1 foot = 12.6 × spherical candles per sq. ft.
apparent candles at 1 foot = foot-candles
foot-candles = lumens per square foot (19)
foot-candles = 12.6 × spherical candles per square foot
foot-candles = ap. cp. at 1 foot
feet = any number (immaterial)

For small flat surface sources only, and only for relatively long distances:

(The "apparent candles" refer only to the source, and only to the direction perpendicular to the surface, but at any distance. The "foot-candles" refer to the flux density (or illumination) of the source or to that of the beam, as stated. The flux refers to that on one side only.)

lumens = 3.14 × apparent candles (24)
lumens = 3.14 × foot-candles (of beam) × feet^2
spherical candles = 0.25 × apparent candles (25)
spherical candles = 0.25 × foot-candles (of beam) × feet^2
apparent candles = 0.318 × lumens (24)
apparent candles = 4 × spherical candles (25)
apparent candles = foot-candles (of beam) × feet^2
apparent candles = 0.318 × foot-candles (of source) × sq. ft. (27)
candles per square inch = 0.00221 × foot-candles (of source) (26)

$$\text{foot-candles (of beam)} = \frac{\text{apparent candles}}{\text{feet}^2}$$

$$\text{foot-candles (of beam)} = 0.318\,\frac{\text{lumens}}{\text{feet}^2}$$

$$\text{foot-candles (of beam)} = 4\,\frac{\text{spherical candles}}{\text{feet}^2}$$

$$\text{foot-candles (of source)} = 3.14\,\frac{\text{apparent candles}}{\text{square feet}}$$

$$\text{foot-candles (of source)} = 452 \times \text{candles per square inch} \tag{26}$$

$$\text{square feet} = 3.14\,\frac{\text{apparent candles}}{\text{foot-candles (of source)}} \tag{27}$$

$$\text{feet}^2 = 0.318\,\frac{\text{lumens}}{\text{foot-candles (of beam)}}$$

$$\text{feet}^2 = 4\,\frac{\text{spherical candles}}{\text{foot-candles (of beam)}}$$

$$\text{feet}^2 = \frac{\text{apparent candles}}{\text{foot-candles (of beam)}}$$

DISCUSSION.

President Bell:—I wish to call the attention of the Society to a very valuable piece of work which was done by Dr. Hyde with respect to the comparison between a luminous surface and its point value. Dr. Hyde found that any surface or linear source, viewed from a point distant from it more than five times the linear dimension of that source, gives practically a point distribution within about one per cent.

Dr. Clayton H. Sharp:—This paper takes up a subject in which I have been much interested, namely, the clarifying of our notions regarding what goes on in the distribution of light, not only from sources such as are ordinarily dealt with, point sources, but from surfaces, and emphasizes the value of the notion of luminous flux.

As I understand it, Mr. Hering has attempted to simplify these matters, to make them clear, and to bring out relations which are not generally understood. Now I wish to express my appreciation of the large amount of the very valuable matter which this paper contains. I wish also to deprecate certain aspects which the paper has taken on. I do not think that Mr. Hering has in all cases made things simpler by the treatment which he has given to the subject. Taking up first the three more important measures and their units, they are:

Flux, or radiation: Common unit, 1 spherical candle; official unit, 1 lumen.

Intensity: Common unit, 1 candle; official unit, 1 hefner.

Illumination: Common unit, 1 foot-candle, official unit 1 lux.

Now, in one way it is true that one can make the unit of flux 1 spherical candle, but I do not think that has been done. I think that what Mr. Hering is giving here is a new unit, the spherical candle as a unit of flux. That is something we have known nothing about formerly, so that instead of simplifying things he is adding something which we really do not need.

Now, we have had the mean spherical candle-power of a source of light, that is, its average intensity in all directions in space. We can all understand what that means. That has been considered as a unit of intensity.

We have already, and have used, as a unit of flux, the lumen which is here called the "official unit." By what right it is called the "official" unit I can guess, but I do not know. The lumen as a unit of flux we understand to be the flux emitted by a source of unit intensity, in a unit solid angle. It has been defined and accepted as such, and works out conveniently in our illuminating engineering work, and is a useful thing to have. I do not know why a new unit of flux should be interjected here, namely, the spherical candle, which far from being "common" is most uncommon as such.

In the next line the "official" unit of intensity is given as a hefner. Of course, our German friends would like the hefner to be considered the official unit of intensity, but it is not the official unit of intensity in this country, and I submit that we are very much interested in what is the official unit in this particular country. We are not so much interested, perhaps, in what some lopsided congress on the other side of the water has tried to legislate into an official standard.

In the same way the lux is given as the "official" unit of illumination. Now, so far as I know the only even semi-official statement as regards the lumen and the lux, which we have on record in this country, is given in the Rules of the Standardization Committee of the American Institute of Electrical Engineers, and in these Rules the lumen is defined in terms of the candle with which we have to deal, and the unit of intensity is defined

as the candle as maintained by its proper custodian, the Bureau of Standards in Washington. Further than that we need not go except in the gas lighting industry, where we have to deal with legal enactments on the subject, which compel us to resort to the old standard candle, as such, and to use it as such.

I do not quite agree with the statement a little further on that "Flux of light is quite analogous to flux of magnetism, or to flux or flow of electricity, more generally called a current of electricity." I think it is analogous to the electro-static flux about a charged conductor, or more properly the electro-static field of a conductor connected to one pole of an alternator.

I fail to see how it conduces to the simplification of our units and our practice to introduce a unit solid angle which has not become the accepted unit solid angle. To be sure, we can get a unit of flux in spherical candle-power, which is the new unit Mr. Hering proposes, if we introduce a new unit solid angle, but how that all conduces to simplification is a thing that I do not see, but I can see how things will be simpler if we stick to one thing than they will be if we add things which are not required. The introduction of another unit gives an additional series of equations so that we have presented to us two equations for the same thing, which I think is quite confusing.

Mr. Hering makes a distinction between our "common" lumens and the "official" lumens, which I suppose are not common lumens, but with which they, the "official" lumens, are connected by a factor of 0.88. I have commented already on the status of the lumen in this country, as defined by the American Institute of Electrical Engineers. The lumen, it is stated here, is based on the hefner unit. Now, there has been a congress, which I have referred to as a lopsided one—because a number of countries of some importance, this one included, were not represented—in which the lumen was defined in this way: That it was based on the French unit, the bougie décimale, and the statement was made that for practical purposes the bougie décimale could be represented by the hefner unit.

Now, we know by actual comparisons of the candlepower of incandescent lamps, as measured in France, where their value is given in the bougie décimale, and where they should know what the bougie décimale is, if any one knows it, with the candlepower

of the same lamps measured in this country that there is no practical difference, no really determinable difference between their bougie décimale and our standard. The congress, which was held at Geneva, must have been wrong in saying that the bougie décimale and the hefner were identical in value, because if we defined the lumen, official or unofficial, basing it on the bougie décimale, as the unit of intensity, we get the exact value for practical purposes which we have in our "common" lumen, and the lumen which is based on hefner units becomes the uncommon one, which would be used in Germany and in any of its scientifically dependent countries only.

I think there is a chance for misconception arising from Mr. Hering's radiation diagrams. The radiation from a point is shown to be a sphere, the radiation from a line source is shown to be a cylinder. In the case of a line source in which all the radiation came out normal to that source, the relation would be true, but we do not have that kind of sources. Consequently the diagram which is shown for the line source, or for a portion of the line source, is not correct, because a line source will radiate in all directions, except exactly along its axis. In the case of a very long line source, one cannot assume the law of inverse squares to hold for the whole line.

As the president has just pointed out, Dr. Hyde has established the relation that at five times the length of the source, from the source, one can assume the inverse law to hold. In the case of a vacuum tube, at five times the linear dimension of that source away from it, it can be photometered with a fair degree of accuracy. It acts like a point of light, at a distance from it, just as does a "searchlight." That is to say, it radiates in all directions, which means that the diagram given by Mr. Hering for a line source is not a correct one. Each element of the line source, like the vacuum tube, will radiate in all directions, and a small section of it can be considered as the center of the sphere. A similar remark holds with the plane surface. A plane surface will radiate in all directions in general, excepting exactly parallel with its surface.

There are a great many other things in this paper which are of very great value, which deserve very careful study, and from which the meat, I am sure, cannot be extracted without a great

deal of attention—more than I have been able to give the paper—and I think we are very greatly indebted to Mr. Hering for calling these matters to our attention and putting them in such a shape that we can use them.

Mr. Alfred A. Wohlauer:—Mr. Hering's paper seems to the speaker to be one of the most notable presented at this convention, as it gives to the illuminating engineer a clear conception of the fundamental units of our science. It is especially valuable in view of the existing inaccuracy in regard to sources of light which cannot be considered as point sources but must be recognized as lines or surfaces of light.

However, in order to simplify the calculations of the illuminating engineer, it seems to me important to distinguish only between the two ideas of light and illumination. Light, the cause or as Mr. Hering pointed out, a power, should be measured in flux values, and illumination, the effect, in flux densities. In this connection, I wish to refer to Mr. Hering's paper where he says: "A statement of the amount of flux alone, without any further specifications, is, however, not sufficient for industrial purposes; what enables one to see is not the amount of flux, but its density, hence it is necessary to specify the density also, or else the flux may be useless for the specific purpose." What we see by, is the illumination, which is a density and should be measured as such, light, however, the cause of illumination, need only be given as a flux, which can be utilized in many different ways. It can be concentrated on a small area or diffused over a wide range. Moreover it is not necessary for our calculations to state its original density, either in candlepower or foot-candles.

In his paper Mr. Hering says:

"Suppose it is desired to illuminate a room having an inside surface of 1,000 sq. feet to an average of 2 foot-candles. According to formulas (16) and (15), the total flux required will be $1000 \times 2 = 2000$ lumens, or $(1000 \times 2) \div \pi = 160$ spherical candles. The latter figure shows directly that about 10 lamps of 16 mean candles will give the desired flux. The same figure can be obtained less directly from the lumens by means of formula (8). This value of course refers only to the direct light from the lamps; the walls and ceiling will also illuminate each other, hence somewhat less than the above value of candle-power will

suffice; this correction is described in text-books and need not be explained here."

Now if a plane having an area of 1,000 sq. feet is illuminated by a certain number of mean spherical candle-power utilizing the total flux, and if this plane surface be bent into a sphere of equal contents, does it not seem strange that the illumination on this surface is larger than on the plane, and that less light and less flux would be needed to illuminate the same area, with the same amount of illumination?

Dr. E. P. Hyde:—Mr. Hering has given us what I think is a very valuable co-efficient for the conversion factor, namely, the relation between foot-candles and candles per square inch, but I do not believe that I can quite agree with Mr. Hering in the statement made by him reading: "It will be shown below that the other unit in which flat sources of light are often expressed and measured, namely, 'candle-power per square inch,' often called the brightness, is an unnecessary and misleading unit, which introduces complications; the unit of illumination can always be used instead of it."

Now, according to our definition of illumination, a perfectly black surface could be very highly illuminated. The intrinsic brightness of that surface, considered as a light source, however, would be 0. The conversion factor which Mr. Hering has given is the candles per square inch of a perfectly diffusing surface, with an absorption co-efficient of 0 and to that extent the conversion factor is of value, but there is an inherent and essential difference between *illumination* and *intrinsic brightness.*

I should like to take advantage of this opportunity to call attention to a point which I think could well be considered by our Committee on Nomenclature and Standards, in regard to our idea of flux density, or flux. Practically, we use flux one way, but we define it in a slightly different way. Unless I am misinformed, the only congress—to which Dr. Sharp has referred as a lopsided congress, and which certainly was a lopsided congress—the only congress which defined these terms specifically was the Geneva Congress, in which the idea of flux was specifically stated in terms of a solid angle.

Now, it seems to me that the proper way to define flux would be, as we naturally use it in practice,—in terms of the quantity of

luminous energy flowing across a surface of unit area per second. In other words, make specific flux a point function, if you will, in space. If one wishes to argue backwards from the effect in space to the source producing the flux, he argues back correctly through the solid angle, if the source is a point source; if it is not a point source he argues back to a source of such and such candle-power, provided it were a source. If the specific flux at any point in space in any direction be defined as the quantity of luminous energy per second flowing across a unit area of surface normal to the given direction, there is obtained a definition of flux density which is perfectly general, and which, moreover, conforms to actual practice. The total flux from the source would then be the integral of the flux density taken over a closed surface enclosing the source. If the source were a point source, or an extended source, or if the closed surface contained three or four sources, one would get the total flux over that closed surface from all the enclosed sources. At any point in space, one would be dealing with the conditions in space, and there would be no difference whether the luminous energy came from an individual source or from several sources, or even whether in addition some of the luminous energy was the result of reflections from walls or ceiling.

I also want to second what Dr. Sharp has said in regard to the statement as to the spherical candle not being the common unit of flux. Moreover, I do not believe we can say that the official unit is a lumen based on the hefner candle, because the so-called official unit,—if I get my information from the same source as Mr. Hering obtained his,—was that defined by the Geneva congress, and I should say that the Geneva congress was not in any sense official.

In reference to what Dr. Sharp has said in regard to the diagrams, I believe that Dr. Sharp did not use a very happy illustration of the vacuum tube as a line source, in the sense of having a cylindrical radiation. One must distinguish between a line source that is a surface, and that would radiate cylindrically, and a line source that is made up of a number or volume of points radiating in all directions. If I recall properly Dr. Sharp said that for a line source there would be radiation in every direction except along the line. Such would be true for

a surface like a Nernst filament, which would be a better illustration. For the vapor tube there is a considerable radiation along the line,—in fact almost as much as in any other direction.

I want to state that, although I must confess to have worked out a geometrical theory of radiating surfaces, Dr. Bell himself has drawn the practical conclusion which he stated in regard to the numerical relationship. I do not recall the data sufficiently well myself to say whether it is right or wrong, but I am sure if Dr. Bell has drawn the conclusion, it must be right. For a circular radiating surface there certainly is a very definite relationship between the diameter of that surface and the distance from the surface at which one can assume the inverse square law to hold, but I have never stated the conclusion quite so concisely, or so practically, as Dr. Bell has done.

Mr. E. L. Elliott:—In regard to the definition of photometric units: the fact that such authorities as Mr. Hering and Dr. Sharp are directly opposed in their individual views as to the most common unit I think is sufficient evidence of the chaotic state still existing in the mensuration of light. The term "mean spherical candle-power," or "spherical candle," as Mr. Hering puts it, is older than lumen, and far more generally used at the present time; and so far as it has been understood at all, it has been taken to refer to quantity, or "flux," of light. When, for example, a particular lamp is said to give 8 spherical candle-power, and another 16, there is no doubt about the meaning intended, namely, that the latter gives twice as much light as the former. It is evident that one spherical candle is the unit, of which 8 and 16 are multiples. I believe that the spherical candle as a unit of flux will be understood by ninety-nine where there would not be one found who would know the meaning of lumen. The comprehension of the difference between light as a quantity, or flux, as commonly expressed by the term "spherical candle," and as a mere intensity, as expressed by the common term candle-power, is none too common at the present time, and has been sufficiently difficult to promulgate. It seems to me unwise to cast doubt upon the term by any hair-splitting considerations of pure mathematics. What illuminating engineering stands most in need of at the present time is a true comprehension of the meaning of the terms and measurements with which it deals.

The term spherical candle-power has the sanction of usage, and after all is said and done, that is the most potent authority in such matters.

Dr. Sharp objects to considering the hefner as official, since it is used only in Germany. I should like enlightenment as to where we go for our official "candle-power" standard in this country. I strongly suspect that search would land one in the Reichanstalt, in Berlin. I find on reading the report of the committee on standards that candle-power means three different things in three different countries. Whatever else may be said of the hefner, it at least has the virtue of meaning one particular thing.

As to Dr. Sharp's criticisms of the radiation diagrams, I would call attention to the fact that Mr. Hering is professedly dealing with pure mathematics, and that a mathematical line is of infinite length, and a surface of infinite extent. It is a perversion of his statements to consider the physical representation of these quantities as the actual quantities with which the author deals. His mathematical reasoning is plainly correct if properly interpreted.

Mr. D. McFarlan Moore:—I consider the paper a timely resume of the present day condition of our units, with the emphasis on the present day, because an examination of the titles of the papers at this convention shows that about 30 per cent. of them deal either directly or indirectly with natural light, which indicates that our final standards, therefore, must be standards which in some way are based on natural light.

In my opinion, all of our present day standards of light are only temporary. I have hope that the vacuum tube will finally be selected as the standard, not only because it is most suitable for reproducibility, but because of having a correct intrinsic brilliancy and correct color values.

The title of this paper is "Calculating and Comparing Lights from Various Sources." When I finished reading it I wished there was another paper, an addition to it, entitled, "Calculating and Comparing the Illumination of Lights from Various Sources." Such a paper would cover a field of great practical importance, and the method adopted would probably result in deducing a single numerical figure to represent each system of illumination, by

dividing the product of the mean foot-candles and the area by the watts.

Mr. Carl Hering:—Concerning Dr. Bell's remarks, I hope some day somebody will make a similar test to show how far we can trust the correctness of Lambert's cosine law.

Concerning the remarks of Dr. Sharp, I was well aware of the fact that he disagreed with me on the question of the spherical candle; I wrote the paper notwithstanding this, because in my opinion Dr. Sharp is wrong. I have tried to limit this paper chiefly to facts. It seems to me it is a matter of fact, a mathematical or physical fact, and not a matter of opinion, whether spherical candles are measures of flux or not. In the common expression

$$\text{lumen} = 4\,\pi \times \text{spherical candles}$$

the factor $4\,\pi$ is a mere number or ratio and therefore is not a physical quantity, that is, it has no "dimensions" in the language of the physicist. Hence according to one of the first principles of physics, multiplying a physical quantity, like spherical candles, by a mere number, cannot change its physical character or dimensions; and as all equations must balance physically as well as algebraically, it must necessarily follow as a physical fact, that spherical candles are the same kind of a physical quantity as lumens, namely, flux.

Another physical proof is the very common expression

$$\frac{\text{watts}}{\text{spherical candles}} = \text{efficiency (so-called).}$$

It is well known that an efficiency (or inefficiency) is a mere number or ratio, and therefore the two quantities "watts" and "spherical candles" must both be the same physically, according to well known principles of physics. But watts are the same kind of a physical quantity as lumens are, namely, power or rate of work, hence spherical candles must also be the same physically, that is, they are flux.

As we call watts per spherical candle an efficiency, then I claim we must consider spherical candles to be a measure of flux. If any person does not want to use spherical candles as a unit of flux, he can cross out in my paper the formulas involving them and use only those in lumens. They both give correct results, the difference is merely that some calculations are simpler when made

in terms of lumens, and others when made in terms of spherical candles.

As to the Geneva congress, all I could do was to state the results as I found them, and it is a fact that the only official definition of the lumen was that of the congress in Geneva held in the year 1896. That congress was the first international body to define a complete and definite set of photometric terms and units, including their interrelations. Whether that congress was strictly official or not, I do not know, but I believe it was. It does not seem to me that it makes any difference. It is certain, however, that the action of the Geneva congress was the first and only action ever taken to date by any international body on a complete system of photometric units, that it was the first to name the lumen, and the first to point out that it was a true unit of flux; it not only pointed out that the lumen could be defined in terms of the candle-power unit, but also that it could be defined in terms of the illumination unit, thereby connecting it not only with point sources, but with surfaces as well, in which latter case the angle is not involved in the least. Whether the congress was official or not, it would be very ungrateful not to admit that it did very creditable, able and useful work in calling attention to the usefulness of flux in photometric calculations and in giving us a rational set of simply-related units which we are using today, except that we have changed the numerical values. I cannot agree that it is proper to call this congress "lopsided," as Dr. Sharp has done publicly.

Notwithstanding Dr. Sharp's statement, I still maintain that it was right to state in the paper that there is a small difference beween the lumen used in Germany (where the hefner is used) and the lumen used in this country. I consider our lumen a hybrid, because the original or foreign lumen was defined in terms of the hefner unit, while we are using the same term lumen but are defining it in terms of our candle, which is numerically different. It is however, not irrational to do this provided it is clearly understood that our lumen is numerically different from that of the foreigners who first defined and used it.

As to Dr. Sharp's remarks concerning flux, I still maintain that flux is a true form of power, it is as correctly convertible into watts, as pounds and ounces are convertible into each other,

or feet and miles, hence luminous flux is truly analogous to a flow of electric energy, which is also power. Lumens represent a flow or radiation of energy.

As to the solid angle, Dr. Sharp criticized my use of the sphere as a second unit for solid angle. I see no reason why we should not do so, just as we use a circle as a unit of plane angles, besides the degree, when we speak of semicircles and quadrants, There may be reasons why the other unit sometimes is preferable, but that does not mean that it is absurd to use a sphere as a unit solid angle; it makes some calculation simpler. The spherical candle is simply a unit like the lumen but referred to the sphere as the unit solid angle instead of the absolute unit. The sphere as a unit is already in common use in the term spherical candles; I found it to be in use and did not create it as a new unit, as was alleged by Dr. Sharp.

As to Dr. Sharp's rather positive remarks about Figs. 2 and 3, the illustrations are strictly correct, notwithstanding his opinion. He has not read the paper, as these figures do not refer to a finite line or surface, but to infinite ones. I believe it was in his address before this Society a year ago that he himself used a formula which involves this very Fig. 2, namely, the formula that the candle power of an infinite line varies inversely as the distance, and not as the square of the distance.

As to Dr. Hyde's remarks, I think his point is well taken, with the exception that I do not see why we should make any distinction in our measurements between reflected light and direct light. Why should we say that because light is reflected from a white ceiling, we must measure it in different units than when it comes from a window or through a white lamp shade? In my opinion we should measure them all in the same units, whether reflected or direct, because I see no reason for making a distinction.

I do not agree with Dr. Hyde that the absorption factor must necessarily be 0 in my conversion factor 452. This relation holds good for all absorption factors, provided this factor is included. When I referred to "illumination" in foot-candles, I referred to either the incident or the reflected flux density. I agree with Dr. Hyde that we ought to have a definite term for the reflected foot-candles.

I agree with the remark of Mr. Elliott that one good reason for using the spherical candles as a unit of flux is that it is a familiar unit, and we all know how to calculate it, whereas the lumen is a new and less familiar one.

Mr. Carl Hering (Communicated After Adjournment):—That I am not alone in using the spherical candle as a unit of flux, as Dr. Sharp claims, is shown in "Electrical Engineering" by Franklin and Esty, in the chapter on Photometry and Illumination, in which it is repeatedly stated that the spherical candle is a correct measure of flux, and that it is distinctly different from a candle. The lumen used in this country is not even mentioned, that term being limited in this book to the original lumen as defined abroad. While I may have been the first to call attention to the physical fact that a spherical candle has the same dimensions as a lumen or a watt, in a book published over four years ago, I maintain that it was merely pointing out a fact and not "creating" a new unit, as Dr. Sharp claimed.

That "nobody uses the sphere as a unit solid angle," as claimed by Dr. Sharp, is also an error. The sphere has always been the unit necessarily implied by definition in the term "hemispherical candle," meaning half of the whole unit, just as the circle is the unit plane angle in using the expressions semicircle and quadrant. Moreover, the sphere is often the most convenient unit solid angle to use, as it avoids the calculation involving the factor π.

Dr. Sharp in his paper on the integrating sphere, read before this Convention, himself repeatedly uses the term "mean spherical candlepower" and "total luminous flux" synonymously, as representing the same kind of a quantity; multiplying by a constant cannot change the nature of a physical quantity. Like many others, he has been using the spherical candle as a measure of flux, unconsciously. To abandon the spherical candle entirely in favor of the lumen, would mean to require a division by the troublesome 4π every time we started the very common relation "watts per candle," which would then necessarily become "watts per lumen." Thus to make a frequent calculation tedious when it is now the acme of simplicity, would be very seriously objected to by all those using this relation.

Our lumen, although a hybrid unit, is amply justified, if it

be clearly understood that it is defined in terms of our candle and is therefore different from the original lumen. The Bureau of Standards at Washington, whose practice we should all follow in such matters, has not adopted any specific unit of light flux, but it has been its custom in measuring light "to use the lumen taken, however, in terms of the candle maintained at that Bureau instead of in terms of the hefner as originally defined by the Geneva Congress." The above is quoted from a recent communication from that Bureau.

In criticising Figs. 2 and 3 in the paper, Dr. Sharp said the rays do not pass out perpendicularly from the line or surface when the light is diffused. As is usual in mathematical physics, the radiations shown by the arrows in these illustrations represent the *resultants* of all of the individual ones; the figures are therefore not incorrect as Dr. Sharp claimed in such positive terms, but are quite in accordance with the usual practice in mathematical physics. I assumed this to be generally known, but it seems it is not. I have therefore added the word "resultant" in the revision of the paper.

Dr. Hyde's objection to using the word "illumination" for the flux density of reflected light also, has been anticipated in the paper, in which this objection is realized; but for want of a better term and not wishing to create a new name, I used it, though unwillingly. The chief point in the paper concerning this, is that both the incident and reflected "illumination" (more correctly, flux density) are physically alike and correctly measurable in terms of the same unit "foot-candles;" the name given to the reflected foot-candles therefore does not affect this and is of less importance. In view of Dr. Hyde's remarks, I have added the word "reflected" before "illumination" in several places in the revision of my paper.

Dr. Kennelly suggested to me subsequent to the appearance of my paper that the already familiar term "intrinsic brightness" could consistently be used in referring to the light reflected from an illuminated surface in the same way as illumination is used to refer to the light falling on to the surface. This would be quite consistent now that it has been shown that such "brightness" can be properly expressed and measured in foot-candles. I consider the suggestion a very good one and regret it is too

late to use it in my paper. I would recommend, however, using merely the word "brightness" stated in foot-candles, as the additional word "intrinsic" is superfluous, the term brightness being itself an expression of a density as distinguished from a total quantity of flux. Moreover, we do not say "intrinsic illumination."

Mr. Wohlauer's remarks are answered in part by the above. I differ, however, in his statement that the flux density need not be stated in practice; it is flux density and not flux alone which enables us to see. It might be advisable to use the decalux instead of the badly named foot-candle, but the latter term has unfortunately gotten too common to hope for reform in its name, desirable though it would be. In reply to his other statement, white walls will increase the illumination of bodies in the room, but how much, is a matter not touched upon in the paper. The usual formula for this was said by Mr. Millar, at this Convention, to be wrong.

ENGINEERING PROBLEMS IN ILLUMINATION.[1]

BY ALFRED A. WOHLAUER.

The vitality of the illuminating engineer has not yet been demonstrated in spite of the fact that since his appearance marked progress has been made in advanced lighting and in the methods of solving problems of illumination. Nevertheless, the illuminating engineer has not met with general recognition, and even in his own territory, for instance, on the part of the lamp and fixture manufacturers the opinion prevails that the illuminating engineer is only an ephemerous manifestation. The reason therefore must be seen in the fact that the science of illuminating engineering is not yet fully developed and that by the layman, as well as even by the illuminating engineer himself, all kind of work is looked upon as illuminating engineering which has nothing to do at all with engineering and which could be performed by almost anybody having common sense in connection with commercial ability. Illuminating engineering is more, and it is the duty of the illuminating engineer to show what real illuminating engineering is striving for, what can be accomplished by the illuminating engineer, and by him only, and which means and ways are offered to realize his intentions and to execute his plans.

It is the object of this paper to present a conception of the duties of the illuminating engineer, to point out and to develop problems which have to be solved by him, to give an idea of the elements and fundamentals an illuminating engineer has to master in order to be able to carry out his work and thus to lay down a clear and convincing proof that illuminating engineering is an individual profession.

Before the advent of the illuminating engineer it was the duty of the architect to design the illumination of buildings. This condition explains why the illuminating engineer is quite often induced to encroach on the territory of the architect and to enter in some kind of conflict wih the more artistical and orna-

[1] A paper presented at the Second Annual Convention of the Illuminating Engineering Society, Philadelphia, October 5-6, 1908

mental ideas of the architect. The illuminating engineer however is an engineer in the first place and can prove his justification only by engineering feats without venturing into drifts which lead neither to his destination nor to success. However, he must enforce the recognition of his figures and calculations disregarding every other limitation but practicability, efficiency and economy.

The illuminating engineer is an *engineer* and has the duty incumbent upon every engineer in general, that is, most practically and economically to utilize the sources in nature for the use and convenience of mankind. Illuminating engineering therefore means to procure illumination as efficiently and economically as possible.

In order to do this, three steps have to be performed whereby the illuminating engineer has to lend his hand:

Firstly, the sources of nature have to be brought into a form convenient for light production.

Secondly, the thus available energy has to be transformed into light.

Thirdly, the sources of light or illuminants have to be correctly and efficiently utilized for illuminating purposes.

The first step is performed in the central stations (gas, electrical, etc.) which produce and supply energy in a convenient form for light production, but have also the policy, especially in this country, of furnishing light directly so that the duty of the illuminating engineer, who knows the requirements in connection therewith, is to assist the central station to offer the best possible services.

The second step concerns the illuminants and their manufacture, whereby the assistance of the illuminating engineer is required in order to secure the best light distribution, and economy of the lamps.

The third step, the outlay of illumination plans, is the real field of activity of the illuminating engineer it is, therefore, the main object of this paper.

However, aside from illumination plans the attention of the illuminating engineer is called to various other subjects which he must master, at least to a certain extent, before he enters into his proper field of activity. There is an analogy in the case of

the electrical engineer, who must acquire auxiliary knowledge of water turbines, steam engines, etc., before he is so far advanced as to take up the problems of electrical machinery, which is his duty proper: The illuminating engineer must be well posted as to the production of gas and electricity, etc. He must be most thoroughly familiar with all kinds of illuminants, their construction and economy. The illuminating engineer, furthermore, must have some idea of the physiology of the human eye as well as of the nature of daylight, of optics and photometry in general, in addition to the fundamentals in mathematics and physics with which practically every engineer must be acquainted.

The chief engineering work of the illuminating engineer, however, consists in the outlay of illumination plans; in what follows real engineering work will be demonstrated, so that it may be considered as a short preliminary treatise, a survey, so to speak, of the science of illuminating engineering.

The first signs of illuminating engineering can be traced back as far as 20 years, when in the time between 1884 and 1889, men like A. P. Trotter, A. Blondel, Wybauw, Weissenburch, etc., did important pioneer work. Not much attention was paid to their work, probably for the same reasons which to-day retard the progress of illuminating engineering, but also on account of the fact that the arts of lamp making and reflector design were not developed as much as they are to-day. It is interesting to note that the first manifestation of illuminating engineering took place in a time when the arc lamp just began to gain ground (street illumination in Paris) and when the incandescent lamp was just out of the days of its infancy, while the latest progress of illuminating engineering coincides with the advent of the tungsten and flaming arc lamp. It is also remarkable that even in these comparatively early days, the necessity of illuminating engineering was recognized. A. P. Trotter, who as far back as 1883 wrote his classical paper on "Uniform distribution of light" states the following in the April issue of the London *Illuminating Engineer,* 1908, regarding a paper which he wrote in 1892.

"The principal object of my original paper was to attempt to enable engineers to predetermine, specify for and provide a definite illumination. While it failed to be utilized in this way to any appreciable extent, other writers have from time to time calculated and published similar curves.

Engineers may have considered this too laborious to apply in practical cases, and the illumination of streets, railway stations, etc., has been for the most part carried out either by adding to the number or to the power of lamps, until the illumination was sufficient, or by trying experiments with lamps at various heights and distances. One excuse for this unscientific procedure was that, in general, nobody knew how much illumination was wanted."

An engineer must be able to predetermine the expected result by calculations based on practical experience; illuminating engineering is therefore only engineering if the expected result—that is a satisfactory intensity of illumination—can be precalculated with a certain degree of exactness. Some of the problems involved will be discussed in what follows.

In order to simplify and systematize this work, a distinction will be made between the following two groups: "Uniform illumination by a single lamp" and "Uniform illumination by a multitude of lamps." Practical experience has demonstrated that uniformity is the chief requirement for good illumination. Due to its adaptability, the human eye adjusts itself according to the highest intensity of light in its field of vision, so that less illuminated spaces appear darker than they actually are, and they involve not only a waste of energy but also a strain upon the eyes. Uneven illumination is therefore unsatisfactory; the discussion in this paper will therefore be confined to problems of uniform illumination.

Uniform illumination by a single lamp, singular illumination, or as it was also called by the author "sporadical" illumination, was the first problem of illuminating engineering. A single lamp was at the disposal for the illumination of the surrounding space, and it was recognized that in the closest neighborhood of the lamp, the intensity of illumination was greater, and, it decreased rapidly with the distance from the lamp. This condition being considered not very favorable nor economical, an effort was made to influence the light emitted by a lamp in such a way that a more uniform illumination could be obtained over larger areas and at greater distances, especially in connection with street lighting. Incidentally it may be mentioned that the problem of street lighting has not been satisfactorily solved up to our present time. Unless it is the object of street lighting to mark a thoroughfare and its crossings, in which case a single lamp

at each corner will be sufficient, streets and open spaces ought to receive general illumination so that the eye of the passers-by is not blinded and annoyed by continuous change of the intensity of illumination.

Singular, or sporadical, illumination ought to be confined to small areas, as they are encountered in the cases of individual desk lighting, billiard table lighting, etc., or in small living rooms, dining rooms and the like, where only a certain limited part of the room should receive the full amount of illumination, while the corners, ceilings, etc., may be kept in a "cozy" darkness.

General illumination, or uniform illumination by multitude of lamps, is to be employed in the majority of cases where large areas are concerned, as in office buildings, department stores, halls, auditoriums, theatres, streets and squares. Although this problem was subject to some interesting work of investigation by Trotter and Blondel in determining the effect of a combination of a number of lamps suspended at different heights and distances, no final solution of the problem has been arrived at.

These two problems, uniform illumination by a single lamp and uniform illumination by a multitude of lamps are the two problems of illuminating engineering which will be looked into in the following. Both can be solved either by using certain lamps without reflector or by combining a certain number of lamps into one unit or fixture or by employing reflectors which make it possible to distribute the light of a lamp or a number of lamps in any desired way.

UNIFORM ILLUMINATION BY A SINGLE LAMP.

Uniform illumination can be provided for by a single lamp or lamp-unit either when the lamp by its special construction uniformly illuminates the area under consideration, or when a number of lamps are combined into a fixture which answers the above purpose, or when use is made of reflectors which distribute the light of a single or a number of lamps in such a way that uniform illumination is obtained. These are three problems of the illuminating engineer which offer a large variety of solutions and open a vast field of interesting and strictly engineering work.

A lamp or lamp-unit which will provide for uniform illumination over a certain area must have a certain polar candle-power

curve,[1] as is represented in Fig. 1 which indicates that the candle-power, which just underneath the lamp is minimum, increases rapidly with the distance from the foot of the lamp. So far as the author could ascertain, this problem was investigated and mathematically and graphically discussed for the first time by A. P. Trotter in 1883 in his paper on uniform distribution of light, which was mentioned above and will be quoted again.

Considering at first lamps which in consequence of their form and construction directly provide for a uniform illumination, it must be stated that there are on the market only a few lamps which do this over an area enclosed by an appreciable solid angle. The best example is the enclosed arc lamp which uni-

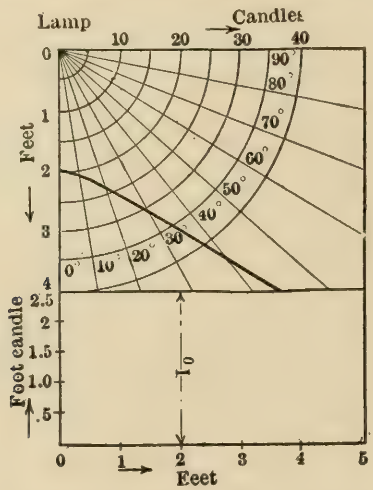


Fig. 1.—Uniform Illumination with One Lamp.

formly illuminates an area enclosed by an angle of about 50 degrees. As to the incandescent lamp, originally the tendency was to design the lamp so that the area uniformly illuminated was as large as possible, and the double oval filament of the carbon incandescent lamp was considered to answer this purpose to a fair extent. At the present time, however, efforts to directly influence the light distribution of incandescent lamps have been abandoned in view of the more satisfactory solution by means of reflectors. The new metal-filament lamps, tantalum and tungsten accidently favor such uniform illumination by the individual lamps on account of their exceedingly low end-on candle-power which, therefore, from this point of view should not be considered a drawback, while the tendency of several lamp manufacturers

[1] *Electrical World*, Dec. 21, 1907. Fig. 1.

of increasing the end-on candle-power does not appear to be generally justified.

The combination of a certain number of lamps into a fixture chandelier, etc., in order to obtain uniform illumination over a certain area, which is the second problem in illumination by a single lamp unit, offers interesting possibilities in its solution.

A number of lamps can be arranged in a circle so that the illumination underneath the center of the circle has a certain intensity which depends on the number of lamps and on the area of the circle. The lamps suspended in a perpendicular position send their maximum intensity in a horizontal direction and the whole fixture will have a light distribution which could be compared with the polar candle-power curve of a metal-filament lamp

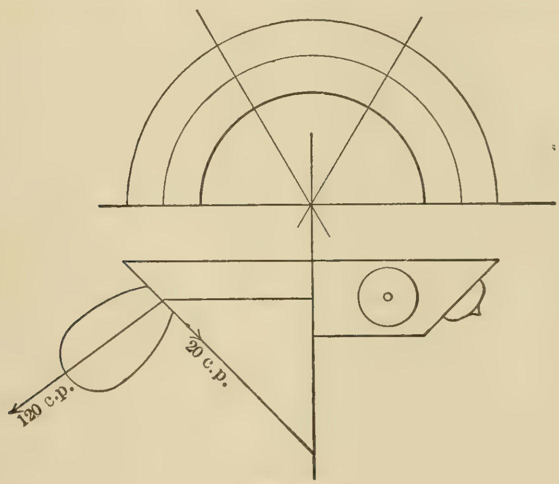


Fig. 2.—Chandelier of Six Reflector Lamps Yielding Uniform Illumination.

in which, roughly speaking, also a number of illuminants are arranged in a circle. The lamps could be suspended, however, also in an inclined position and provided with reflectors so that no light is wasted inside the fixture while the maximum intensity is issuing under a certain angle, as illustrated in Fig. 2. By proper arrangement it is possible to produce a fixture which approximately gives uniform illumination over a considerable area. It is apparent that numerous variations and designs of this kind present themselves to the illuminating engineer.

The next possibility of producing uniform illumination by means of a single lamp is offered by the use of reflectors in connection with a lamp. Broadly speaking, one can transform the light distribution of a lamp, of whatever shape its polar candle-

power curve may be, into a distribution yielding uniform illumination. Although the problem of the design of reflectors is one of the most interesting ones of illuminating engineering, not much has been published concerning it.

The action of any reflector is based on the collection of the rays of the illuminant, or the dispersion of them by means of reflecting surfaces which turn the rays striking them into the desired direction. Starting therefore from a certain intensity of illumination required on a certain plane, it is possible to ascertain the distribution of the light flux of a lamp to produce the required intensity of illumination at the different parts of the plane. This fact suggests, of course, a certain method of designing reflectors which diffuse the light underneath the lamp and concentrate it into the further distant regions according to the law prescribed by the polar candle-power curve shown in Fig. 1, so that a large amount of the flux is sent to places remote from the source of light while the nearer space just underneath the lamp receives a correspondingly small part of the total flux of the lamp. Starting from such considerations, it is possible to determine the angle under which the flux of the lamp has to be reflected in order to answer the requirements.

This special problem of designing a reflector which distributes the light of the lamp in order to obtain uniform illumination can be considered as one of the oldest problems of illuminating engineering. In fact A. P. Trotter, states that even as far back as 1802 the importance of this problem was recognized by Smethurst, and Paul as well as by Fresnel, about 50 years ago. In considering this problem Trotter assumes that the area to be illuminated is divided up into rings of equal area, the radii being as $\sqrt{1} \div \sqrt{2} \div \sqrt{3} \div$ etc. As the same quantity of light must be thrown into each ring in order to produce the same illumination, the rays of the illuminant must be deflected and distributed so that the tangents of their inclination to the vertical are as $\sqrt{1} \div \sqrt{2} \div \sqrt{3} \div$ as is illustrated[1] in Fig. 3.

There are two possibilities of solving this problem, either by regular reflection or by a so-called dioptric method. The latter was used by Trotter and successfully introduced by Blondel who enclosed the illuminant in a glass globe provided with reflecting

[1] From Trotter's article, *Proceedings*. Inst. of C. E., vol 37, page 348.

and refracting glass prisms of especially calculated profile, as indicated in Figs. 4 and 5. These globes were named by Blondel

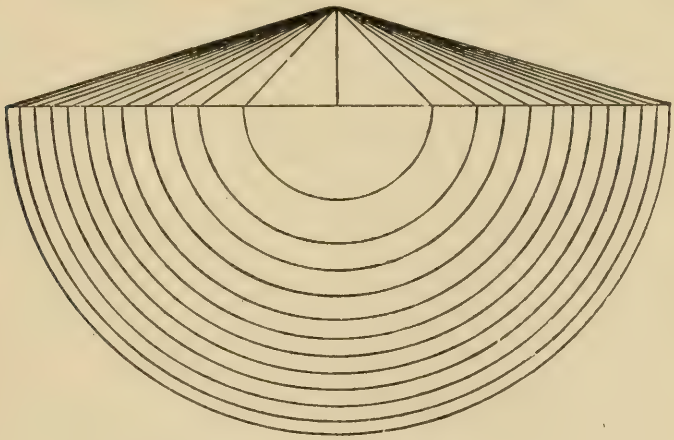
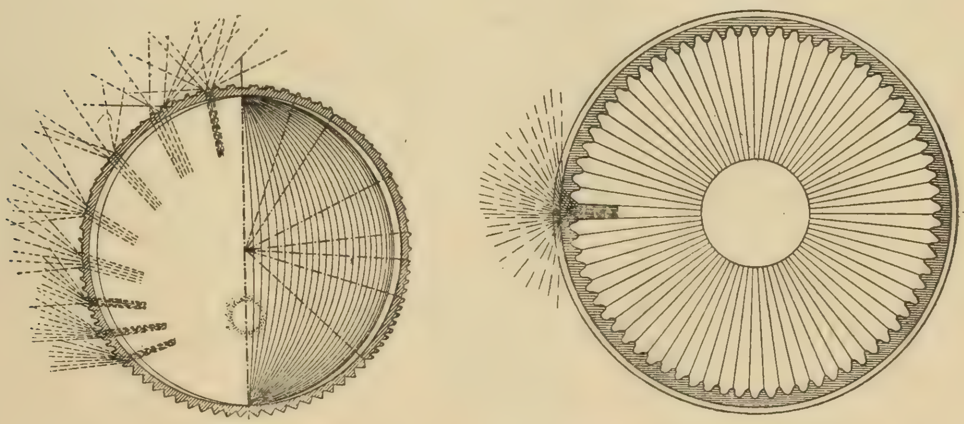


Fig. 3.—Uniform Distribution of Light.

"holophane" a word derived from the Greek, as they appear to be "luminous all over." They form the origin of a vast number of various kinds of prismatic globes and reflectors which have grown more and more in public favor all over the world and prove to be a strong backbone of illuminating engineering.

The use of regular reflection was not considered advisable by



Figs. 4 and 5.—Prismatic Globes.

Blondel who found reflectors of "silvered glass too fragile and those of metal too difficult to preserve from oxydation." Another drawback of mirror reflectors is the glare produced by them which limits their use; nevertheless, it must be admitted that

they are the most efficient reflectors and would have quite a future if it were possible to overcome the above objections.

The actual designing of reflectors is accomplished by

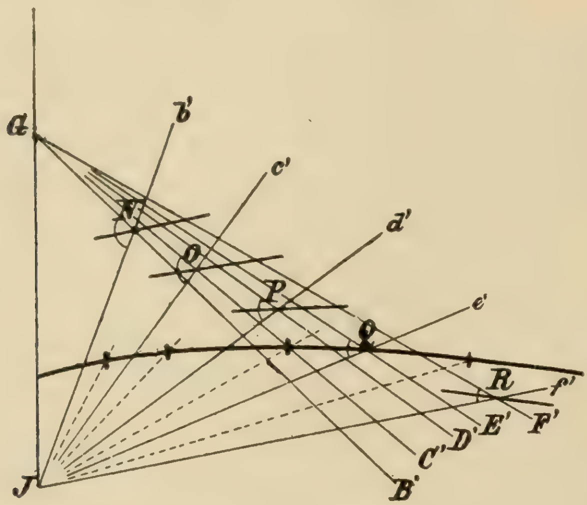


Fig. 6.—Graphical Reflector Design.

either graphical methods or a combination of numerical calculations with graphical constructions. A graphical method of designing reflectors is indicated[1] in Fig. 6 and a modification thereof in Fig. 7, as employed by the author.

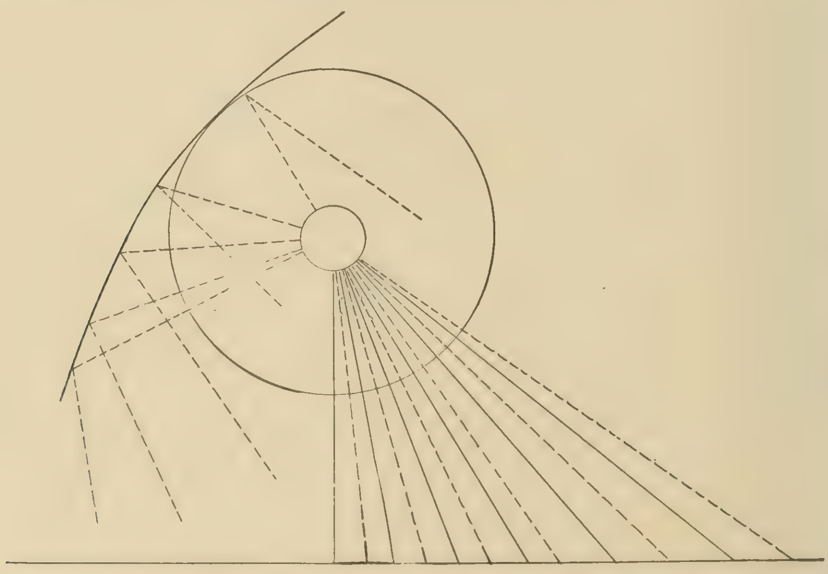


Fig. 7.—Reflector for Uniform Illumination.

The problem of a numercial and graphical determination of the shape of the reflectors for uniform illumination has been

[1] Herzog and Feldman. *Handbuch der elektrischen Beleuchtung*, 1907.

taken up of the late by E. W. Weinbeer[1] who gives the following solution:

A source of light the polar candle-power curve of which is a circle described around the illuminant as a center can be utilized for uniform illumination by employing a reflector in the following way. The intensity of the uniform illumination may be equal to the illumination just underneath the lamp. As illustrated in Fig. 8, the illumination produced by the lamp without reflector will vary as indicated by the lower illumination curve, while the uniform illumination is represented by the upper straight line. The additional flux of light which must be thrown into the various

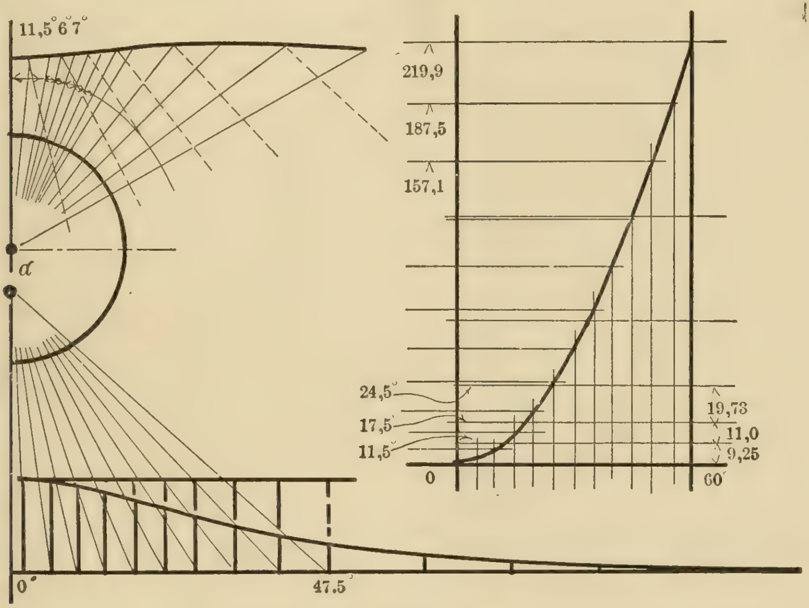


Fig. 8.—Weinbeer Reflector.

annular zones can be calculated and the flux of light which emanates into the upper hemisphere can be utilized by reflection for this purpose. The angle under which the light must be reflected is calculated numerically and graphically so that it is an easy matter to ascertain the shape of a reflector for this purpose.

Uniform illumination by a single lamp, or sporadical illumination, is the only problem of illuminating engineering which has been successfully investigated before our time, especially by A. P. Trotter[2] and Blondel[3] and an examination of their works will be a great benefit for the student of illuminating engineering.

[1] *Elektrotechnischer Anzeiger*, August, 1908.
[2] *Transactions* of the Inst. of Civil Eng., London, 1883.
[3] *London Electrician*, 1894, 1895, 1896, 1897.

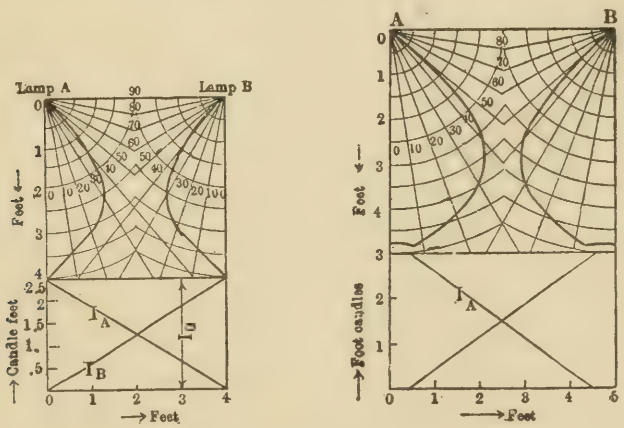
UNIFORM ILLUMINATION BY A MULTITUDE OF LAMPS.

The problem of uniform illumination by a multitude of lamps is another important part of the work of the illuminating engineer. It has not been fully solved up to this time, although Trotter, Blondel and others started 15 years ago to investigate this problem. On account of the low efficiency of the illuminants of that time, it is probable that this problem was not considered as important as the sporadical illumination which is much less expensive. With the present available very efficient illuminants, however, the illumination by a multitude of lamps is decidedly more attractive and offers the only correct solution for the illumination of large spaces. The problem involved consists of the combination of a number of lamps in such a way that the resulting intensities of illumination at different points of the plane are equal or their deviation is as small as possible. Of late, Dr. L. Bloch,[1] J. Herzog and others have systematized the methods of solving problems of this kind by basing their calculations on a so-called average intensity of illumination with a consideration of the difference between maximum and minimum intensity. E. W. Weinbeer deserves further credit for having investigated this matter thoroughly in connection with the illuminants of the various polar candle-power curves and having determined the number of candles necessary to provide for uniform illumination of a certain intensity under the assumption that the number of lamps used is infinite so that the numerous overlapping illumination curves lead to an almost exact uniform illumination. Weinbeer's calculations and investigations are based on the assumption that no reflector is used in connection with the illuminants and that reflection from wall and ceiling is negligible; and it is obvious, as Weinbeer states himself, that his figures are exact only when the number of lamps employed is very large, in which case practically the total lower hemispherical flux of the lamps is utilized. If however, the illumination of a lamp is concentrated on a small area in such a way that it disappears before or at the foot of the next lamp, the inexactness is practically done away with.

As was pointed out by the author in several articles in the *Electrical World,* straight illumination curves, as illustrated in

[1] Dr. L. Bloch. *Grundzüge der Beleuchtungstechnik*, 1907.

Figs. 9 and 10 lead to a very simple solution of the problem of uniform illumination by a multitude of lamps. The lamps can be conveniently arranged by dividing the area to be illuminated in squares, placing a lamp at the corner of each square. Assuming a single straight-line illumination inclining from a maximum intensity just below the lamp to zero just below the adjacent lamp, as illustrated in Fig. 9, the illumination will not be quite uniform, but will possess maxima at the intersection of the diagonals. Using a somewhat more complicated straight-line illumination curve, Fig. 10, which is horizontal for lengths of .085 of the the distance between two lamps, the point of intersection of the



Figs. 9 and 10.—Uniform Illumination from a Number of Lamps.

diagonals will also receive the same illumination as the point just underneath the lamp and a still better degree of uniform illumination will be obtained. By further changing the illumination curve, a somewhat greater accuracy of uniform illumination can be obtained. (See Foell, *Trans.* I. E. S., Nov. 1907). However, in view of the fact that ideal uniform illumination could never be reached in practice, practical illumination curves such as illustrated in Fig. 10 are fully satisfactory and even such as illustrated in Fig. 9 would answer the purpose; by increase of the height of suspension, a still higher degree of uniformity can be effected.

It is an interesting problem to ascertain whether the polar candle-power curves corresponding to illumination curves such as illustrated in Figs. 9 and 10 can be realized in practice. There exist again the three possibilities of either employing

lamps which by their special construction or design answer the purpose, or of combining lamps into a unit or fixture which yields the desired polar candle-power curve, or of employing reflectors by means of which the light of the single lamp may be reflected and distributed correspondingly.

Of existing lamps, the Nernst and the flaming arc come nearest to the above requirements and could be conveniently used directly for this purpose with a certain small error. It is beyond the scope of this paper to discuss the advisability and possibilities of such a solution.

The combining of a number of lamps into a chandelier or fixture is a very simple and interesting problem of the illuminating engineer which offers to him a variety of solutions and modifications, and numerous suggestions to the fixture manufacturer.

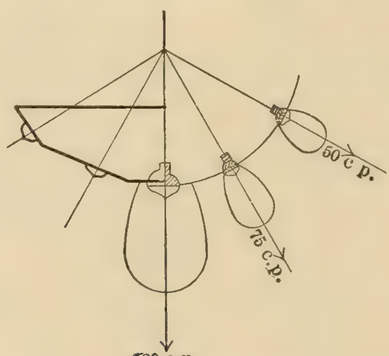


Fig. 11.—Chandelier Yielding a Straight-line Illumination Curve.

Lamps with or without reflectors, the polar candle-power curves of which are known, can be combined in such a way that the correct amount of light intensity is issued into the proper direction as called for by the final polar candle-power curve of the fixture. Such a possibility is indicated in Fig. 11, which may be considered to show only one of a long line of similar solutions. Such fixtures can be used in large halls, ball rooms and certain stores of a more exclusive nature where the architect finds it desirable to use chandeliers and fixtures rather than distribute a number of ceiling lamps over the space to be illuminated.

In places where an elaborate display is not required, as in school rooms, office buildings, etc., or in theatres, concert halls etc., where fixtures are objectionable as they may obstruct the view, it is better to arrange a multitude of lamps as near to the ceiling as possible and to combine the light of the different individual

lamps into uniform illumination. In this case, reflectors must be employed, and it is interesting to ascertain the shape of such reflector. For the design of the reflectors, it must be borne in mind that the light of the lamp is concentrated over a rather small area confined by an angle which as a rule is not larger than 45 degrees. To use the prismatic method for this purpose does not seem advisable since in the case of prismatic reflectors, a cer-

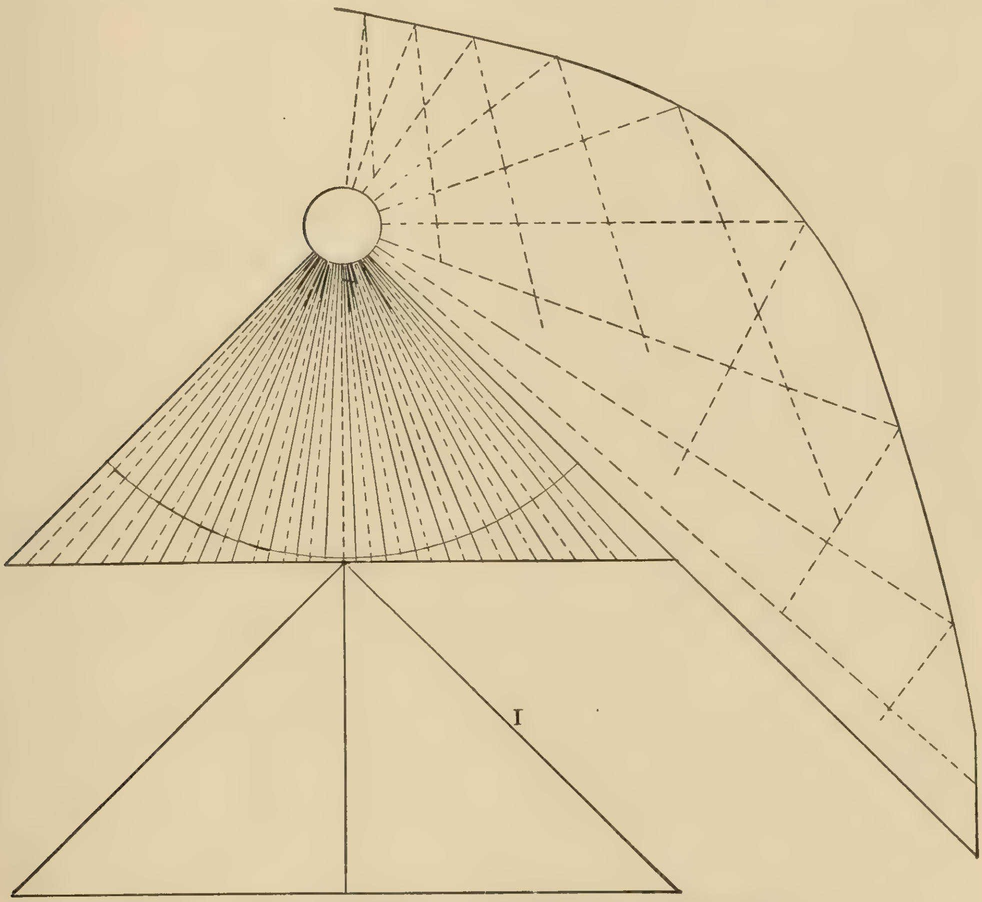


Fig. 12.—Reflector Yielding a Straight-line Illumination Curve.

tain amount of light always passes through the glass into the upper regions. Only a reflector with opaque cover would be adaptable.

Mirror reflectors however are better, if the glare arising from them is not objectionable or can be done away with. The shape of such a reflector designed by the author is indicated in Fig. 12.

It has been shown in the above that a vast field of strictly engineering work is offered to the illuminating engineer in regard

merely to the arrangement of illumination plans. Considerations as to efficiency of the lamps have not been taken up nor has the very important problem of the calculation of the number of lamps required been touched as this would lead too far. Nevertheless, it is demonstrated that illuminating engineering is a real branch of the engineering art which in view of the necessity of illumination for public welfare and convenience should not be neglected by anyone.

DISCUSSION.

Mr. Albert J. Marshall:—I do not desire to direct any criticism directly at Mr. Wohlauer's paper, but simply take this opportunity to view a couple of points I desire to bring cut. While I agree in the main with Mr. Wohlauer that the average illuminating engineer today is as yet not fully recognized as representing a distinct profession, which to a measure is due to the fact that there are many people who have termed themselves illuminating engineer but who have scant idea of the qualifications necessary successfully to carry out the work which may be entrusted to them, yet I do contend that there are a few competent men who, through ability and much earnest work, have established for themselves a recognition in the minds of the public, especially the lighting interests.

To my mind, one of the chief reasons for the lack of recognition on the part of architects, decorative designers, etc., has been due to the fact that up to the present time, in the majority of cases, illuminating engineering principles have been presented as being almost purely mathematical, subordinating almost entirely the important part that aesthetics play in the work as a whole. There have been many papers written and much discussion on the parts that aesthetics and utilitarism should play in the matter, but as yet I do not feel that such interests have come to an understanding.

There seem to be two distinct elements working at the present time in the matter of advancing what might be termed the proper use of artificial light. One is working along almost entirely the mathematical side, while the other is pushing to the fore the necessity of considering first of all the aesthetic require-

ments. There is certainly a common ground on which these two elements may meet, and I wish to place myself here on record as stating that the sooner this result is accomplished that much sooner will the profession be recognized by those people who have in many cases the authority in the matter, namely, the architects.

To my mind, the question of economy has almost been run into the ground. In fact, this one thing seems to be the chief, and in many cases the only though given when a lighting system is being designed. Engineers who do not understand aethetics certainly with training can realize to some degree what is ordinarily termed "good taste," and can embody it in their work. To my mind, it will be the engineer who combines "good taste" with economy who will eventually attain the goal to which we, as illuminating engineers, are striving.

The subject of economy has been held too long before the central stations and gas companies in this country. While I fully believe that the average supply station and gas company today is desirous of having its customers obtain full value from all energy sold to them for lighting purposes, to say nothing of the power side of the matter, yet I do feel that the central stations and gas companies would co-operate even more heartily with the illuminating engineer if they felt that their interests would, to a measure, be protected.

To give an example of the point which I am now attempting to bring out, take, for instance, two spaces of similar dimensions and treatment and used for the same general purposes. Two illuminating engineers are called in to design lighting systems for these spaces. One engineer will specify a lighting system in which he endeavors to obtain the greatest amount of illumination on a given plane for the least expenditure for energy, irrespective of the appearance of the lighting units when in place. The other engineer in designing a lighting system will study the treatment of the space and suggest a system which will harmonize in all details with its surroundings, then have delivered as economically as possible the required amount of intensity of illumination. The latter engineer will, perhaps, use more energy than the other engineer referred to. Assume now that both installations are satisfactory to the owner; which, might I ask,

would be the most satisfactory to the central station? The answer to such a question is evident.

It is best, therefore, to consider the beautiful as well as the purely utilitarian side in our work, and thus to produce results which will be satisfactory to every one.

Mr. L. R. Hopton:—While the paper contains valuable scientific information, I cannot accept the statement reading: "However he must enforce the recognition of his figures and calculations disregarding every other limitation but practicability, efficiency and economy." Of course it might be argued that the term "practicability" can be very broadly interpreted, but my experience has been that the average illuminating engineer is prone to reason along narrow lines. Such statements as this, I think, tend to antagonize architects and others who are interested in proper architectural and ornamental treatment, and are fair neither to them nor to ourselves.

Mr. V. R. Lansingh:—I do not believe everybody will agree with Mr. Wohlauer when he states: "In places where an elaborate display is not required, as in school rooms, office buildings, etc., or in theatres, concert halls, etc., where fixtures are objectionable as they may obstruct the view, it is better to arrange a multitude of lamps as near to the ceiling as possible and to combine the light of the different individual lamps into uniform illumination. To use the prismatic method for this purpose does not seem advisable since in the case of prismatic reflectors, a certain amount of light always passes through the glass into the upper regions. Only a reflector with opaque cover would be adaptable." There are very few of us, including Mr. Wohlauer, who would agree to darken a ceiling under the chosen conditions.

As regards the question of uniform illumination, it may be of interest to call attention to three new types of prismatic reflectors which will shortly be available. The first of these, which is called the "extensive" type, and gives a broad distribution of light, similar to the well-known bowl prismatic reflector, is especially adapted for the lighting of a small room with a single lamp or group of lamps, a narrow store with a row of lamps down the center, and similar cases.

The second type, which is known as the "focusing" type, throws a strong concentrated light, of which the end-on candle-

power is practically four times the rated horizontal candle-power of the lamp. Such reflectors are adapted for very high ceilings, window lighting, etc.

The third, or "intensive" type, gives a polar candle-power curve between these two, that is, it produces a broad, concentrated light, and is especially adapted for places where several lamps are used close to the ceiling, such as in large department stores, etc.; also for a long, narrow store where a row of lamps is hung over each counter.

With these three types of reflectors, practically 90 per cent. of lighting problems where a general illumination is required can be treated satisfactorily. The "intensive" type of polar candle-power curve is considerably different from anything heretofore presented and promises to fill the "long-felt want."

Mr. E. L. Elliott:—Most of this paper is taken up with the discussion of the problem of uniform illumination. I am inclined to take issue with the author's first premise. There are certainly very many cases in which uniform illumination is neither practicable nor desirable. Such is the case, for instance, in office lighting. I believe that the best illuminating engineering practice is to produce a very mild general illumination, with strong localized lighting for desks and work tables. In the lighting of work shops, the same method may be used to advantage. Again, in residence lighting, there is comparatively little necessity for uniformity. In the dining room, and the library, localized lighting for the tables is preferable. Furthermore, after all has been done to secure uniformity, it will usually be found that there is a large variation, amounting often to 50 or 100 per cent; so long as the minimum is not too low, however, such differences are of no consequence, and in fact are imperceptible to the eye.

The theoretical problem of securing uniform illumination, which involves both the calculation of reflecting surfaces, and the proper placing of the light units, is a most interesting one; it must not be forgotten that it is, nevertheless, a theoretical problem, and the discrepancy between theory and practice is usually very considerable. Considering a source of light as a point, it is comparatively easy to determine the conditions for obtaining a given distribution of light by means of reflection or refraction; but when one deals with light-sources as they

are, of considerable dimensions, he finds that his theory is in error to such an extent as to render the actual design of apparatus fully as much an art as a science. The results will depend upon the skill with which the compromise between theory and practice can be effected. I do not deny the value and importance of theory; I merely wish to emphasize the importance of practice.

President Bell:—The chair would simply like to express a word of appreciation concerning Mr. Wohlauer's paper, in the direction of the usefulness of the methods which he has noted for the laying out of reflectors for especial purposes. I want to say that, as a matter of fact, one can employ the graphical methods which Mr. Wohlauer has pointed out, or the cognate methods which suggest themselves to anyone who understands the theory of it, and lay out reflectors that will produce results which at first sight seem absolutely impossible. The success of these methods in practice will fully justify their use.

Mr. Alfred Wohlauer:—As to the remarks of the first speakers, I wish to say that I did not desire to disregard the aesthetic side of the illuminating art. I wanted merely to point out and prove to the architect that the illuminating engineer knows more about lighting than the architect and is therefore useful to him. If we enter into any artistical competition, with the architect, If we enter into any artistical competition with the architect, and will never hold our own. Nevertheless, I admit that it is a very good thing for the illuminating engineer to have certain knowledge ot artistic rules and an artistic intuition. If he has such, he will be much more able to follow the ideas of the architect. For his own work, however, he must know above all the fundamentals of illuminating engineering, which have nothing to do with architecture.

As to the remarks of Mr. Lansingh, I may say that I do not see anything ridiculous in the use of opaque reflectors suspended close to the ceiling, be it in a theatre, or anywhere else. When suspended close to the ceiling, reflectors need not be translucent, for the ceiling is, so to speak, the last step of light, and there is nothing beyond to illuminate. Therefore, if the reflectors on the ceiling are mirror reflectors, or opaque reflectors of any kind, they are fully correct, whether in a theatre or anywhere else. Of course, it must be admitted that there might be some

glare issuing from a mirror reflector, unless the lamps employed are frosted, and there is no doubt that means should be employed to avoid or to dispense with such a glare.

Mr. Elliott has touched a subject which was discussed at a previous meeting in connection with structural difficulties in the illumination of office buildings. I believe it is rather convenient for the illuminating engineer who designs the illumination of an office building to provide for a general illumination which is sufficient to enable a man at the desk to read by, rather than to employ a local or sporadical illumination, which may prove to be inadequate in the future due to the changing taste of the occupants of the offices. However, it is not always left to the illuminating engineer to say whether he prefers uniform illumination of large spaces or individual desk lighting.

In regard to the illumination of dining room tables, as well as of desks, etc., I may say that this subject was treated in my paper, such an illumination being called sporadical. I believe it is very important for the individual illumination on special tables or desks in dining rooms or libraries to be uniform, and to follow the curve which is indicated by Fig. 1; this whole problem has been discussed in the first part of my paper.

As to the design of reflectors, I must admit that I have not quite the same experience as Mr. Elliott has, and I do not know whether it is possible to realize the graphical constructions in practice, but Dr. Bell has stated that it is possible to do so.

DISCUSSION OF THE PHILADELPHIA CONVENTION PAPERS BY THE NEW YORK SECTION.

THE RELATION BETWEEN CANDLE-POWER AND VOLTAGE OF DIFFERENT TYPES OF INCANDESCENT LAMPS.

Mr. P. S. Millar:—In the discussion at the Convention an effort was made to learn from Mr. Cady what practical bearing the results of his investigation would have upon the measurement and rating of lamps. Although the author stated that his investigation was one of scientific interest, and that he had not endeavored to apply it commercially, yet it was felt that in considering it in our Society, we ought not to neglect any possible practical application. I have tried to learn Mr. Cady's test results, but up to this time have been unable to do so.

From the exponents given in the paper, I have computed his probable results, and I find that throughout a range of 50 per cent. candle-power with that corresponding to 3.1 watts per candle as the center of the range, they vary by no more than one per cent. from experimental results. In other words, it would appear that one may still feel that, for approximation results, he may apply a constant exponent throughout a range of 50 per cent. candle-power.

Incidentally, it may be noted that experimental results have indicated that for a treated carbon filament lamp, of 3.1 watts per candle, 5.5 is about the correct exponent and that when this is applied to the per cent. change in voltage, it will yield the per cent. change in candle-power with a very good degree of accuracy.

THE INTENSITY OF NATURAL ILLUMINATION THROUGHOUT THE DAY.

Mr. P. S. Millar:—Two interesting points regarding Mr. Lewinson's paper were brought out at the Convention. Mr. Hering, in discussing the paper, pointed out that the brightness of a white surface illuminated by the sun at midday in the summer time is of the same order as the brightness of an ordinary incandescent gas mantle. The second point was made by Mr. Lewinson in the paper; it is to the effect that with 2 foot-

candles of natural illumination at twilight and at dawn, one is unable to read ordinary print, whereas with artificial light of this intensity one is accustomed to feel satisfied.

Mr. E. L. Elliott:—In regard to the intensity of the Welsbach mantle as compared with white paper in sunlight, was not the entire area of the apparent space occupied by the mantle taken instead of the actual space occupied by the threads?

Mr. Millar:—I think that is so, although, as far as I remember, Mr. Hering did not bring out the point.

Mr. D. McF. Moore:—The point just brought out by Mr. Millar in reference to 2 foot-candles, which is also put in the form of a question by Mr. Lewinson in his paper, has been explained in several different ways, but nobody seems to have mentioned the matter of pupilary dilation and contraction. I have my doubts whether there is any difference between 2 foot-candles of natural and artificial light. It is a well known fact that a great many eyes require as much time as half an hour to dilate sufficiently to get a correct value of a given illumination, and I believe that if the observers had been for perhaps a half hour in a room with the light at about 2 foot-candles, they would have been able to observe the readings on the photometer without any trouble.

Mr. A. J. Marshall:—Regarding the proposition of pupilary dilation, I wish to say that inasmuch as Mr. Lewinson made observations all night with a light of very slowly changing intensity, it seems to me that the statement of Mr. Moore does not hold good. He, I understand, had been there for considerable more than half an hour taking readings with this intensity and there was only a very slight change throughout that time.

Mr. D. McF. Moore:—In answer to Mr. Marshall I think one of the striking points brought out by the paper was the suddenness with which the intensity fell with the setting of the sun and that there was by no means, a half-hour for the eye to dilate.

Mr. P. S. Millar:—Referring to the point Mr. Moore has just made, that pupilary dilation may account for this phenomenon, I would point out that the observers had been working in the darkness, and although the change in natural illumination at the time was very rapid, yet in the morning it was a change in a

direction which would not explain the peculiar effect. As the observers had been working in the darkness for sometime, the pupils would have been dilated and the tendency would have been rather to over-estimate the natural illumination in the morning.

Mr. Norman Macbeth:—Was not the value of 2 foot-candles stated to be insufficient to read the instruments? It was said that 2 foot-candles "would be sufficient to read a newspaper," but might not be enough for the proper reading of the fine scales on the instruments.

Mr. L. J. Lewinson:—The photometer scale was vertical. The standard lamp gave only enough light to show the position of the indicator; an auxiliary incandescent lamp was needed to read the scale. I could not read from the note book and needed the illumination from an extra incandescent. lamp, to make notes in the book, with 2 foot-candles of natural illumination.

THE INTEGRATING SPHERE IN INDUSTRIAL PHOTOMETRY.

Mr. L. J. Lewinson:—I wish to emphasize the point brought out by the authors, where they say, "we have been slow to investigate the merits of the integrating sphere, although its simplicity and other meritorious features have been appreciated." The Matthews integrating photometer, which has been used in a few photometric laboratories is a very cumbersome piece of apparatus and from a commercial point of view it is difficult to handle. The integrating sphere is a simple and accurate device, and it should have an important bearing upon the lighting industry.

Dr. A. H. Elliott:—The application of the principle of the integrating sphere is obvious and I hope that the future will show its developments. What is needed more and more in photometric apparatus is simplification, with a view to obtaining accurate results.

Mr. Preston S. Millar:—As showing the accuracy of the integrating sphere under adverse conditions, I may mention that when an incandescent lamp, the bulb of which was painted black on one side, was placed within the sphere, so that one side of the sphere was much more brightly lighted than the other side in so

far as direct light was concerned it was found at first that changes in the orientation of the lamp with such distorted light distribution caused considerable differences in the results. It became necessary to design the sphere correctly, particularly with reference to the screen, before this difficulty could be overcome. The sphere as now constructed is free from error of that kind. With a lamp having such largely distorted distribution as that described, no differences in result are obtained when the orientation of the lamp is changed.

THE CALCULATION OF ILLUMINATION BY THE FLUX-OF-LIGHT METHOD.

Mr. J. S. Codman:—The paper by Messrs. Cravath and Lansingh is very interesting indeed and when I heard it read at Philadelphia I thought that the flux-of-light method might prove very useful in calculation. However, after careful study I have been led to doubt whether the method is as practical as it seemed at first. The table given is of course very practical, although being only a rough approximation. The method of finding the flux in different zones is also very practical. The question is, however, whether the flux-of-light method itself is of any great practical value. The important formula which the authors make use of, namely, "the average foot-candles times watts per lumen equal watts per square foot" expresses simply the fact that the foot-candles desired multiplied by the watts per lumen that are actually effective on the chosen plane give the necessary value of watts per square foot. Now, as the authors have stated, the key to the whole problem is the determination of the proper number of lumens actually effective on the plane; in other words, the determination of the angle which, in the Lansingh-Rolph paper, is spoken of as the effective angle. The question of this angle is in fact the key to the whole problem. One must know this angle in order to arrive at the watts per lumen. The question arises as to the existence of any practicable way to ascertain what the effective angle is. The authors apparently have estimated the value in the following manner. The table gives the watts per lumen as found by actual measurements for different conditions; that is to say, using different kinds of lamps arranged differently in different rooms. Consider the first one in that table,—

tungsten lamps rated at 1.25 watts per horizontal candle-power; etc. Assuming the watts per lumen as given it is possible to calculate the effective angle, but that is doing the thing backwards. Instead of using the effective angle to ascertain what the watts per lumen are, we have ascertained the watts per lumen by actual measurements and then have calculated the effective angle. The effective angle found thus does seem to me to be of no practical value, as one would certainly go to the table for the value of watts per lumen and not re-figure it by the flux-of-light method. It might seem possible, however, that the flux-of-light method could be used in the following way: For one particular layout one could measure the watts per lumen, calculate the effective angle and then use that effective angle for the calculation of illumination in another case. As a matter of fact, however, this cannot be done, because in changing the installation the effective angle would be changed also, even if the only change in the installation were the substitution of another source of light, and all other conditions, including height and position of sources, the color of the walls and dimensions of the room, etc., remained unchanged.

The above relation is more or less evident, without demonstration, but it is well brought out in the paper by Messrs. Lansingh and Rolph. When three bare lamps were used, with dark ceiling, walls and floor, the effective angle was 50 degrees. When three lamps were used with reflectors, the ceiling, walls and floor remaining dark, the effective angle was 46 degrees. On the other hand according to the calculated illumination the effective angles are found to be nearer together, namely, 46 and 47 degrees. In other words, if the ceiling, walls and floor were absolutely black, the effective angles would be equal and one could use the following method:

Measure the watts per lumen effective with one source of light and ascertain the effective angle. This angle can then be used for calculating the watts per lumen from another source of light.

The method here mentioned could be used only with dark walls, ceiling and floor. Nevertheless, it would be decidedly useful. One could assume certain conditions with one source of light

and could calculate the illumination by the old point-to-point method properly applied. Properly applied one could estimate the lumens effective by the point-to-point method. Having done that he could calculate the effective angle and then substituting another light source and calculating by the flux-of-light method, which is much shorter than the point-to-point method he could find the lumens effective with the new source. So far as I can see, this is the only way in which it can be used. I should like to know how others have used it in the past and have them explain it.

Mr. E. L. Elliott:—It seems to me that the flux-of-light method is rather a preliminary operation than a complete method. The error to which the authors call attention, which consists in taking the average of the different values of foot-candles as the average illumination, hardly seems to be an error. I do not see that the average cuts any figure. Talking about average illumination, it seems to me is a good deal like getting the average intelligence of a number of people in a room. The problem of the illumination of a room or a space of any kind, or a street for that matter, in its practical aspects is a question of maximum and minimum intensity, and whether one can see at every point in the room to do what he wants to do; the average is of little practical importance. The method may save some guessing, but it is a question whether one cannot guess more quickly than he can figure it out.

Mr. V. R. Lansingh:—(Communicated after adjournment). Mr. Codman's objections to the flux-of-light method of calculation is probably as valid for this method as it is for the old point-by-point method of calculation, where the effect of walls and ceiling is not taken in account at all. It is perfectly true that the effective angle is determined by working back from actual tests where the lumens per watt are first ascertained, but after one has had a certain amount of experience in working with these constants and understanding the conditions, it is a comparatively simple matter to select the effective angle. Thus, in the case of one building the writer has in mind, the effective angle was only 15 degrees each side of the vertical if account was taken simply of the flux of light which would fall on the working plane.

Owing to surrounding conditions, it was decided to increase the value to 30 degrees and the number of lumens within 30 degrees was calculated and the foot-candles determined by this method. This value was afterwards checked up by the point-and-point method, which led to the same results; although, of course, by a much longer method.

In other words, in order to use the flux-of-light method correctly in cases where no constants are known to cover conditions one has to employ a whole lot of common sense and good judgment, the same as in any problem of illumination, and if one brings to bear such good judgment, the flux-of-light method will save a great amount of calculation. It is in no sense a panacea for an ignoramus who has not had experience or judgment, unless constants to fit the conditions have already been ascertained. Fortunately, in a large portion of the installations which are now going on, the constants as given in the tables fit conditions and can be safely used. Thus, with tungsten lamps in a comparatively large room, if use is made of a constant of from .20 to .25, or, as I prefer to put it, from four to five expressed in lumens per watt, the result would fit nine cases out of ten and it would be safe to figure on this basis.

There is another thing which the flux-of-light method gives and which the point-by-point method does not give without a vast amount of labor, and that is the average illumination throughout the area concerned. It is practically impossible to ascertain this value by the point-and-point method, whereas the flux-of-light method gives it at once. If this method had no other use than this, it would certainly be valuable. Both Mr. Cravath and myself have used this method for nearly a year and we have found that in actual practice satisfactory results can be obtained.

ILLUMINATION OF THE NEW YORK CITY CARNEGIE LIBRARIES.

Mr. J. S. Codman:—What is the distinction between glassware C and glassware D? Were they used in different places.

Mr. L. B. Marks:—Glassware C represents a prismatic reflector having a bat-wing distribution, which reflector is covered by an outer shade of opal glass, green on the outside and white on the inside. Glassware D represents a concentrating prismatic

reflector covered with a shade of the same character as that of glassware C. The fixtures provided with glassware D are used for the illumination of the free standing book cases, whereas the fixtures provided with glassware C are used for lighting the rectangular reading tables.

THE IVES COLORIMETER IN ILLUMINATING ENGINEERING.

Mr. D. McF. Moore:—At the Convention I took exception to the numerical values given in the paper for the carbon dioxide tube, and subsequent to the Convention and the presentation of the paper I arranged with Mr. Ives to make tests to ascertain whether or not the values given in the paper could be corroborated. The values in the paper were for the carbon dioxide tube: Red 100, green 120 and blue 520. The values obtained in the corroborative tests were 100 for the red, 91.53 for the green and 67.8 for the blue, which indicates quite a discrepancy. Moreover, it was conceded that on the day when the tests recorded in the paper were made, the sky was extra blue and that if the day had been a normal day, the average day, there is every reason to believe that the results obtained by certain German tests would have been corroborated. Roughly these are the results of the German tests: Red 100; Green 103; Blue 104, which show that light of the carbon dioxide tube really does equal that of average daylight. It comes within about three per cent. of it and therefore all these tests prove that in the table in the paper, the carbon dioxide tube should have been given the first place as regards approximation to daylight. As to how the error crept in may be explained in a number of ways; but it is interesting to note again that the results were obtained, as the paper says, indirectly. That is the carbon dioxide tube was first compared with an arc lamp, and a flickering arc at that, and it was then compared with an incandescent lamp and it in turn with daylight, so there were four factors. Of course, the subsequent tests were obtained by direct comparison. I wish also to say that the last tests proved that the Ives colorimeter is an extremely practical and valuable instrument and I believe it will prove of great value to the illuminating engineering profession.

Mr. F. E. Ives:—As having made the original measurements at the post office which afterwards, by transcription gave a mis-

leading impression about the carbon dioxide tube, I want to say that I was asked to go to the post office to use the colorimeter without knowing at all what the condition would be there. We had to improvise or build a platform and get up under the ceiling to make the observations on the instrument where it was just barely possible to get one eye over the eye piece by pressing up against the ceiling. We had to use an electric arc lamp as a standard for comparison and the current appeared to be fluctuating tremendously. We could not control the electric arc lamp; one minute it would almost go out and the next it would be very bright, and it was changing in color continually. We simply did the best we could with it. Afterwards the same lamp was connected in another place and compared with an incandescent bulb. I reported the figures obtained with the variable electric arc lamp and they were taken to Washington and compared with other measurements. Now, when I subsequently tested the carbon dioxide tube I compared it with two things: In the first place, the day was an extraordinarily clear one with an unusually blue sky. The tube was compared against the blue sky at zenith and against sunlight reflected from an opal glass. The light of the tube was less blue than the sky at zenith, but twice as blue (relatively to red) as the sunlight reflected from the opal glass; and that corresponds to the estimate I gave at Philadelphia that the light of the tube corresponded to a moderately blue sky.

A medium blue sky would not be accepted as average daylight at the Bureau of Standards. Thus, Mr. Moore's idea of average daylight is bluer than average daylight which would be accepted, for instance, by Prof. Nichols. Nevertheless, there is a point in which I agree with Mr. Moore completely and that is to say in comparing the color of fabrics and that sort of thing, they will more often be subjected to the light from the north sky, coming through a north window, than to sunlight from a south window.

Mr. E. L. Elliott:—I want to express my satisfaction at the corrected figures. I took occasion to remark at the Convention that the discrepancy was so large as to be extremely disappointing I think the last test clears up the matter very well. I believe

it bears out Mr. Moore's contention that one could do no better in selecting a standard white light than to use his carbon dioxide tube. The light from it is something which can always be produced of invariable quality, so far as color is concerned, and I think that the suggestion is a very important one.

Mr. Norman Macbeth:—In connection with the statements: "From these figures the best light of the five for matching colors is that of the Welsbach, while that of the Cooper-Hewitt, an extremely selective source, exhibits wide deviations. That the latter should be the case is to be expected," and "Hence in the case of a selective source the color of a white surface is no guide, either for the eye or for the colorimeter, to the effect on a colored surface," I find in the paper given by Dr. Bell before this Society in June, 1906, some curves from Prof. Nichols' data stating that the Welsbach mantle "shows a considerable departure from the distribution of the normal incandescent body, due not to enhanced temperature, but to powerfully selective radiation." I would like to know if in view of these conditions the conclusions in Dr. Ives' paper are correct.

Mr. F. E. Ives:—The paper under discussion is my son's paper, and he did the work. Personally, with respect to the light of the Welsbach lamp, I know that as compared with daylight, which one is accustomed to use for matching colors and so on, it is quite distinct in violet, that is spectrum violet rays. I do not consider it a very good light for matching colors myself. The light from the carbon dioxide tube would be incomparably better, in fact there is nothing better. The light from an electric arc lamp is good but not an absolutely fixed standard like that of the carbon dioxide tube.

CALCULATING AND COMPARING LIGHTS FROM VARIOUS SOURCES.

Mr. P. S. Millar:—Much of the discussion of Mr. Hering's paper at the Convention referred to his definition of flux units. Our usual practice has been to consider flux as equal to unit solid angle multiplied by 4π times the mean spherical candle-power.

Flux $=$ unit solid angle $\times$ 4π $\times$ mean spherical candle-power.

Mr. Hering gives due attention to this method. He recognizes it and thinks it should be introduced more widely. How-

ever, he mentions another unit of flux as an alternative unit. To make the use of this unit possible, he takes the sphere as the unit of solid angle, which multiplied by the mean spherical candle-power, equals this unit of flux which he calls the "spherical candle."

$$\text{Sphere} = \text{unit solid angle} \times 4\pi$$
$$\text{Flux} = \text{sphere} \times \text{mean spherical candle-power.}$$

Now, the sphere is simply unit solid angle multiplied by 4π. In other words, the 4π factor is applied to unit solid angle to create a new unit of solid angle,—the sphere, after which the use of the proposed unit of flux, the spherical candle, becomes possible. The only way in which the spherical candle can be used is to assume the sphere as the unit of solid angle.

The "spherical candle" is stated by Mr. Hering to be the common unit of flux. I must take issue with him there. I do not think it is. Personally, I have never known of any one using it as the unit of flux except Mr. Hering. We have often used the mean spherical candle-power, but this has been used as the average intensity in all directions about a source. There is no intention, I believe, in the paper to use the mean spherical candle-power as the unit of flux. Mr. Hering specifically states that the unit which has been used in practice "although not generally under the name of flux" is the "spherical candle." I want to repeat that I have never met with the use of this quantity as the unit of flux, and that the only people in this country who have treated of light flux as such have referred to it in terms of the lumen.

The chief objection which has been urged against the lumen is that its use in connection with our unit of light intensity introduces confusion, in that it is used in Germany in connection with the hefner candle. It should not be lost sight of that the use of the lumen in connection with the hefner is unauthorized. The lumen was first proposed by Blondel as the unit of flux, and was adopted at the Geneva International Congress before which Blondel proposed it. It was based upon the bougie décimale as the unit of intensity. Now the bougie décimale is, so far as we can tell, practically the equivalent of our candle-power. In

the very near future we hope to have adopted an international unit of light intensity which will make the unit of light intensity in England, France and America one and the same, and this will be the practical equivalent of the bougie décimale.

In using the lumen with our candle-power therefore, we are making a very close approximation to its authorized value. The use of the lumen in connection with the hefner is based upon the msconception that the hefner is practically the equivalent of the bougie décimale. At the Geneva Conference it was thought this was the case, and that therefore for practical purposes the hefner could be used as the equivalent of the bougie décimale. As a matter of fact, it differs from that unit by about 11 per cent., and the German use of the lumen based upon the hefner is therefore incorrect to that extent.

At the present time, we are growing accustomed to the use of the lumen as the unit of flux. It works out beautifully with our system of computing illuminating efficiencies, and the introduction of an alternative unit which makes necessary the assumption of a new unit of solid angle can serve no useful purpose, and must simply introduce confusion.

In treating of intensity, Mr. Hering gives the common unit as one candle-power, and the official unit as one hefner. The candle-power is the common unit, and so far as we have one it is the official unit in this country. The nearest approach to an official declaration on this subject is the report of the American Institute of Electrical Engineers, which states that the unit of luminous intensity is the candle-power. It does not say that it is based upon the hefner, but declares that it is $\frac{100}{88}$ of the hefner. As a matter of fact, the unit is derived from a group of incandescent lamps in possession of the National Bureau of Standards, at Washington. There is no declaration in favor of the hefner, and the statement that the hefner is the official unit seems to me a most unfortunate one in view of the facts.

In treating of the units of illumination intensity, the foot-candle is given as the common unit and the lux as the official unit. It seems to me that the lux is open to all of the objections which can be urged against the hefner and the lumen together,

while unlike the lumen, there do not exist any reasons for its use.

Mr. Alfred A. Wohlauer:—In regard to the remark of Mr. Millar, I understood Mr. Hering somewhat differently. I believe he did not want to introduce a new unit or spherical candle, but merely wanted to point out that the spherical candle is really a flux value and not a candle value. He says that a lumen is simply the mean spherical candle multiplied by 4π. As I said in the discussion of Mr. Hering's paper, illuminating engineers need not bother with candles if they deal exclusively with light and illumination.

Mr. Carl Hering:—(Communicated after adjournment). Mr. Millar's discussion was in great part virtually a repetition of Dr. Sharp's remarks at the Convention in Philadelphia, and as I have already answered the latter, I refer those who may be interested, to my reply to that original discussion. As he repeats these remarks after having heard my verbal reply to them, he either did not understand them or still does not agree with me. Instead of clearing up the situation he confuses it still more by some mysterious and unexplained distinction between the terms "spherical candle" and "spherical candle-power," which he apparently wants the reader to believe was made by me. I deny having made any such distinction in my paper or at any other time, and would not have made it, as it would merely confuse instead of clarify a situation which is too misty as it is.

That Mr. Millar has never known of any one using the spherical candle as a measure and unit of flux, is his fault and not mine. He will find it for instance in Franklin & Esty's "Electrical Engineering," Chap. X, in which this is the only unit of flux prominently mentioned, the lumen described therein being only the original foreign lumen and not the hybrid one recently introduced here, apparently by Mr. Millar's friends. I repeat that we have all been using the spherical candle as a measure of flux for many years, but apparently without noticing that it really represented flux. Hence I was not suggesting any new unit, but merely called attention to the true existing state of affairs. Mr. Millar apparently is not familar with the well

known principle that physical equations should balance also as far as dimensions are concerned.

He is also mistaken when he says that "the only people in this country who have treated of light flux as such have referred to it in terms of the lumen." A number of years ago and prior to the popular introduction of the present "lumen" in this country, I "treated of light flux" as he calls it, quite thoroughly in my "Conversion Tables," p. 144-149, published in 1904, and there explained the only two then existing units of flux, the original foreign lumen of Blondel, and our spherical candle; our present lumen did not exist then to my knowledge, and was created later. Franklin & Esty's book is another illustration that Mr. Millar is mistaken.

The question of what the present value is of the older candle-power units, is of historic interest only, and of no importance at present. The important point in practice today is that the lumen used abroad today is different from our lumen; and that this should be considered in reading foreign literature, or when foreigners read our literature. This is all that I wished to emphasize in my paper.

I differ with Mr. Millar very decidedly in his statement that the sphere is "a new unit solid angle;" it is undoubtedly much older than the steradian unit, just as the circle is older than the degree or the radian. Also in that it "must simply introduce confusion" to use both the lumen and the spherical candle; on the contrary it often greatly simplifies and facilitates many calculations, as it often avoids the tedious multiplication and division by 4π. The examples in my paper illustrate this. It is like using both the gallon and the cubic foot as measures of volume, or the circle, the degree and the radian as units of angles, or the horse power and kilowatt, etc.,—there is no lack of precedent.

Mr. Millar admits that our candle is not an "official" unit. I believe the hefner was "officially" adopted in Germany and is therefore entitled to be thus called, and that it was therefore quite proper for me to distinguish between them in this way. Mr. Millar seems to forget that the United States is only one country in this world; there are others whose actions also deserve consideration. That there "do not exist any reasons for the use of

the lux" is, to put it mildly, rather uncomplimentary to the foreigners and especially to that able pioneer Blondel, who have given us in the first and only rational system of photometric units, the one used today, and were the first to clear up, by means of it, a very misty state of affairs. It is needless to say that I do not agree with Mr. Millar in this and regret that he thus reflected on his able teachers and leaders abroad.

Mr. Millar's criticisms do not attack the correctness of any of the formulas, relations, deductions, etc. given in this paper, but refer merely to terms and to past history, and hence pertain only to unessential parts of the paper. Those who do not care to avail themselves of the simplification in calculations resulting from the use of both units of flux, may simply cross out the formulas involving the spherical candle—all of the rest are given too.

Those interested in the question of the spherical candle versus the lumen as a unit flux will find a short article by the writer in the *Illuminating Engineer,* Oct., 1908, p. 438. (also p. 444) which explains the distinctions more clearly.

DISCUSSION OF THE PHILADELPHIA CONVENTION PAPERS BY THE NEW ENGLAND SECTION.

STREET LIGHTING.

Dr. Louis Bell:—Among the papers delivered at the recent convention were two which deal with street lighting, one being entitled "Street Lighting Fixtures and Illuminants," and the other "Street Lighting with Gas in Europe." My address in Philadelphia was principally an appeal for more light. It is a fact that the streets of the average American city are very badly lighted, the chief fault being that the lamps are too small for their spacing. In other words the spacing of the lamps is much too extended to give really excellent illumination anywhere in the streets for any considerable distance. The ordinary canon of good lighting abroad seems to be the lighting of the streets to an intensity sufficiently great to enable one to read a newspaper. That result is actually obtained on the chief streets in most of the European capitals. I have repeatedly driven down the streets at night and been able to read fine print all the way by the street lamps alone. Indeed, no city that pretends to do first class lighting fails to have several or a considerable group of streets lighted in that way.

On the other hand the secondary or tertiary streets abroad are not lighted on any particularly brilliant plan, but they are lighted I think more intelligently than our streets in America. These streets are lighted usually with small illuminants, commonly Welsbach lamps, or incandescents, or Nernst lamps. The fault is not with the illuminants but with the fact that there are not enough of them. In the tertiary or outlying streets in suburban districts we commit the blunder also of using the same types of lamps that we would use in the centre of the city and stringing them out. We have arc lamps 500 or 600 feet apart, and these, as seen in suburban districts, are perfectly useless for purposes of illumination, because while they give local light they produce no sensible illumination over most of the street.

In surburban streets what is really wanted is to mark the way

thoroughly, which is best accomplished by small lamps, closely spaced rather than by large arc lamps or powerful gas burners spaced many feet apart.

We also place our lamps as a whole very much too low, in addition to using much smaller units than are common in Europe. The ordinary European arc lamp gives twice as much light as the American and often four or five times as much. In gas practice in some European cities the very large Welsbach mantle is being used under considerable gas pressure; by this means there is obtained a powerful lighting unit which is made to do sterling service, although at considerable cost. Our street lighting has grown up without any systematic engineering work behind it. A city started in years ago with its lighting and contracted for all the lamps it could afford to use. Then as the city grew it used more lamps. In some particular ward a few lamps were located in front of the houses of its prominent citizens, etc., and the territory became finally fairly well covered with lamps in response to the cries of ward politicians. Such is the experience of most of the cities. The fact is that city lighting was not brought up, but "just growed" like Topsy, and the results are very unsatisfactory. However, at the present time in a few cities there are short stretches of street that are admirably lighted. For example, in the upper part of New York there are perhaps two miles of street that are fairly well lighted from the engineering standpoint. In a few of the other cities similar results are beginning to appear.

In America use is made of about 10 kilowatts or so of power to a mile, whereas the proper amount would be from 18 to 25 kilowatts per mile with illuminants of much greater efficiency than those now in use. Consequently the difference is so obvious that it needs no discussion. When our cities are willing to employ a suitable amount of power to light the streets the technical difficulties will disappear.

In my Philadelphia address I casually mentioned one important thing, and that is the unfortunate use of moonlight schedule. The moonlight schedule is about the poorest apology for a lighting schedule which has ever been devised. In the first place the light of the moon by itself when full in our latitude affords

perhaps 0.02 foot-candle,—enough to stumble about by but not enough to be really taken as illumination. A half moon instead of giving one-half gives about 0.1 of the light of a full moon, which is a completely negligible quantity for street illumination. The obvious explanation is that the moon has a tremendous lot of specular reflection which is superimposed upon the general diffused reflection; but whatever the exact cause may be the fact is as stated above. There is only about a week in each month when the moonlight can be considered seriously for street illumination, so that if one attempts to use a moonlight schedule at all, use should be made of about 80 per cent. of the energy necessary for all-night illumination, whereas usually only about 65 per cent. is furnished. For rigid economy I think the best method is that which is used abroad, which is to extinguish alternate lamps at 12 or 1 o'clock. I think in most cities it is not desirable to have anything but all-night lighting, but when it is necessary to economize it is best to pick a proper time and place for extinguishing the lamps and not depend upon the weather and the moonlight.

All of the papers on lighting at the Convention were of considerable interest. They are particularly noticeable in showing the paucity of invention of humanity in dealing with street lighting. Some of the systems are fairly good but most of them are poor, and in our American practice the grievious effect of parsimony is only too noticeable. Abroad the cities often own the plant and frequently the fixtures. In Berlin there has been recently erected in the most conspicuous part of the city two huge bronze fixtures bearing groups of enormous flaming arc lamps,—fixtures perhaps 50 to 60 feet high of bronze, costing about $800 apiece. In Amsterdam, which is by no means a very large city nor an extremely wealthy city, the standard street fixture is a beautiful shepherd's crook affair of steel tube bent into form and costing about $100. apiece. With that amount of funds put into permanent and beautiful fixtures there is no wonder at all that the general effect of the lamp post is much better than seen in America.

It is a curious thing that, strong as the artistic sense is supposed to be in Paris, the fixtures in use in that city are poor. On the street which on the whole is the most brilliantly lighted one

in Paris, with flaming arc lamps from one end to the other, the poles are ugly. Where the artistic sense has come to the rescue, good poles are being used. I think that the foreign fixtures on the whole are not so very much better than those in use in America. The general style of the fixtures is about the same as used here, except that a pole fixture is employed. Where it is necessary to swing a lamp in the street abroad, it is usually suspended from a wire stretched from house to house. The city has authority to do this and simply tells the resident that a man will fix the supports for a lamp upon his residence or place of business, and the owner has nothing to do but greet the man pleasantly when he comes.

Mr. Wrightington's paper on "Street Lighting by Gas" was too brief. I wish he had discussed more thoroughly the gas used in Europe. The ordinary street lighting with the Welsbach lamp is about the same as used here except that the inverted burner is employed much more freely; it is not by any means used universally, but in some cities many are seen. The high pressure lamp is certainly very interesting, and I wish Mr. Wrightington had described it at some length. The scheme is to augment the combustion inside the large mantle and by forcing the combustion to raise the temperature very high and get an efficient lamp of great candle-power. The mantle used is perhaps from 4 to 6 inches long and 2 to 3 inches in diameter, sometimes inverted and sometimes erect, and the gas is furnished to the lamp under pressure maintained in the old types at from 15 to 20 inches of water and up to 50 or 60 inches in the new types. The high pressure does not reach the mantle. It is mostly effective in furnishing to the mantle a great quantity of air and gas, with the result of producing a flame of very high temperature which is sufficient to bring the mantle to a high degree of incandescence and to give a tremendously powerful light. The lamps afford from 500 to 1000 candle-power and sometimes higher.

In some types of gas lamp which have been tried the air is furnished at a pressure with the idea of getting sufficient quantity to take care of an unusually large quantity of gas. The most successful system seems to be the ordinary one of supplying the

gas through special mains under pressure. In the Berlin system, which I examined very carefully, the pressure is 12 centimeters of mercury, about 60 inches of water. Some 2000 lamps receive gas from two pressure stations worked by gas engines, the lighting ignition being automatic. There are values which automatically let on the gas to the pilot flame when the pressure strikes the burner, as the compressors start up the lamps increase in brilliancy. The gas used per lamp was from 25 to 35 cubic feet per hour. The maintenance cost of the mantles is believed to be rather high. The cost per burner is comparable with that of an arc lamp.

The most interesting innovation in the matter of material is the artificial silk mantle which is packed for shipment in a small flat pill-box and can be handled with absolute impunity before it is fired. When put on the burner, and the gas turned on and ignited, the loose bag-like mantle shrinks into definite position. It is then a mantle of the ordinary type, working excellently well.

Dr. A. E. Kennelly:—As I understand it, a special gas main is necesssary for the lamps on the high pressure system, in order to maintain a special pressure, so I suppose the cost of a special set of gas mains must be included in estimating the cost of that system. When Dr. Bell says that the cost is about the same as that of an arc lamp, does he include the cost of mains or merely the gas and fixture?

Dr. Louis Bell:—The mains used are of various types. Those for the high pressure such as I saw in Berlin were of Mannesmann steel tube put together with lead gaskets. Of course such a tube was not rendered necessary for strength, but it was not likely to leak and it is apparently cheap. The cost I have mentioned is supposed to include the cost of maintenance, which is a dubious item. I do not know whether it is the full cost but the cost in Berlin was said to be about $250. per two-mantle post, each mantle affording about a thousand candle-power. The lighting costs where the lamps are furnished by private contract are not quite so great, but are in the same general order of magnitude and I presume are intended to cover maintenance. Of course the exact figures are hard to ascertain, but the cost is about as much as that of the arc lamps in the same cities.

STRUCTURAL DIFFICULTIES IN INSTALLATION WORK.

Dr. Louis Bell:—I should like to mention one snag that the illuminating engineer strikes. I have found a great many cases of rather large rooms in which only wall brackets were supplied for the illumination. When a room is finished in very light color it can be lighted fairly well with wall brackets, but if the finish is dark and the room fairly large, it is almost impossible to get good light with wall brackets. If for any reason side brackets have to be used in such a way, the electrical part should not be put at an angle, because with a lamp pointing out at an angle of 45 degrees, there is no shade known that will give a proper light distribution. If one must use brackets, they should be put fairly high, the lamps pointing down or straight up. For either case there are good distributing shades available to throw the light out into the room. If possible, however, an outlet should be put on the ceiling from which place the light can be distributed fairly well.

Mr. J. S. Codman:—I endorse very strongly Dr. Bell's remarks in regard to the angle bracket. Most certainly there in no shade made which will give a proper distribution under the conditions mentioned.

Dr. A. E. Kennelly:—Not only are there no shades which will give proper distribution but there is no shade which will prevent the rays from shining directly into ones face within a considerable angular range in front of the lamp.

Mr. J. S. Codman:—Of course one can enclose the lamp entirely in a globe in which case the glare is gotten rid of, but good distribution can not thus be obtained.

ENGINEERING PROBLEMS IN ILLUMINATION.

Dr. A. E. Kennelly:—I should like to ask a question. Is it settled that absolutely uniform illumination is the great desideratum? I concede that if a certain amount of illumination is necessary then anything above is excessive, and anything below is not enough. The question is whether a slight departure from uniform illumination in the direction of excess is not at least pleasing and whether there is not a danger in uniform illumination, whereby the absence of contrast and absence of shadow may make a distressing aesthetic effect.

Mr. R. C. Ware:—The question raised by Dr. Kennelly emphasizes the fact that every case must be considered purely on its merits. For an ordinary work-room, draughting-room or library the illumination in general should be such that one can read fairly comfortably anywhere, but there must be particularly bright illumination where the work has to be done. The combination of general and local lighting would have to be varied to suit particular instances, but absolutely uniform illumination, as Dr. Kennelly says, would be very distressing.

Dr. Louis Bell:—I might contribute to this discussion one fact, and that is that the design or reflectors by graphical methods is a perfectly easy thing to do and it does lead to good results. I have had to do it several times recently, conspicuously in the shield on the door over this building where there was a very narrow recess in which it was possible to get only eight tubular lamps in the extreme lower part of the shield. In that case I laid out the reflector quite easily on a drafting board.

SOME EXPERIMENTS ON REFLECTIONS FROM CEILINGS, WALLS AND FLOORS.

Dr. A. E. Kennelly:—I wish to add my endorsement to the great value of this paper and of the one preceding it. The capability of light ceilings and light walls to add to the illumination is brought out very clearly indeed. If these facts were only more generally appreciated I think they would lead to a considerable saving in money value to the nation at large. The paper shows the enormous amount of waste that can and frequently does go on by reason of ignoring the colors of walls and ceilings. The color of the floors fortunately does not matter so much. The increase is due not only the bright ceiling but the co-operation of bright ceilings and walls as shown in the paper. When there are light walls and white ceiling one obtains more than the sum of the constituents, so that two and two do not make four but, as it were, half a dozen.

Each of these papers shows the application of the flux method to the requirements of illuminating engineering, and this paper is, in fact, an illustration of a method laid down in the preceding paper. It is remarkable how in the applied sciences, certainly

in electricity, magnetism and illumination, we stumble upon the fact that we ought to base our units upon flux, but we start off with a point and have to enlarge our ideas from a point, which has no dimensions, to flux, which involves at least two dimensions.

Dr. Louis Bell:—I wish it were more generally remembered that lighting expenditures in a building are continuing charges. If one were to figure these fixed charges, the amount of actual expense caused by simply putting dark paint on the wall, etc., the net result would be rather startling. This refers not only to the color of the walls but also to the distribution of the light. The architect who arranges the lamps badly entails a continuing cost forever upon his client, and yet seems to think sometimes that it is of no particular consequence. The proper arrangement of lamps is a very definite and very great economy which is forgotten more than half the time.

Mr. R. C. Ware:—There is one danger into which a too liberal interpretation of the data given in this paper may lead one. In an ordinary living room where there will not be a particularly close application to any one desk, the eye requires some place where it can be rested, and for such purpose a dark wainscoting or dark lower part of the walls would seem desirable. On the other hand there is no reason at all why so many buildings should be equipped with a heavy dado such as we see nowadays. From the upper part of the ceiling the reflection should most suitably come, but a large part is cut out by the dado. I think the dark walled room has a distinct place in our life but I think its application needs careful regulation.

TRANSCRIPTIONS OF THE

Illuminating Engineering Society

VOL. III. DECEMBER, 1908. NO. 9.

A meeting of the Council was held on December 11, President Bell, Dr. A. H. Elliott, Dr. C. H. Sharp and Messrs. W. H. Gartley, L. B. Marks, H. K. Mohr and Bassett Jones, Jr., being in attendance.

The monthly report on the Society's finances, as presented by the Chairman of the Finance Committee, showed a balance to date of $3041.86, with outstanding bills amounting to $835.17. The report stated also that the expenses of the Philadelphia Convention, which were paid out of the general fund of the Society, amounted to $663.77. The report was favorably received and the bills unpaid were approved by the Council for payment.

It was moved and carried that the Finance Committee be authorized to employ a public accountant to audit the books and accounts of the Society at the end of the fiscal year 1908.

A letter from the Vice-President of the Society in Chicago was read, asking what plans were proposed for the next sectional elections, in the event of the adoption of the amendment to the Constitution now being voted upon. This question was discussed, and the President was instructed to reply to the effect that the Council has no authority to direct the Sections in this matter, but would point out that the simplest course would be to omit holding the January elections and to allow the present officers to serve until the time at which the next election must be held under the new amendment to the Constitution.

In accordance with Article VI, Section 4, of the Constitution President Bell appointed the Committee of Tellers for the 1909 election of officers to be constituted as follows:

W. Cullen Morris, New York
Ralph W. Pope, New York
A. A. Pope, New York
G. T. MacBeth, Mount Vernon, N. Y.
J. T. Maxwell, Philadelphia.

President Bell appointed Messrs. V. R. Lansingh, Preston S. Millar, and Dr. A. H. Elliott, to serve as a Committee on Arrangements for the Annual Meeting of the Society on January 8th.

The names of fifteen applicants were presented, with the endorsement of the respective Boards of Examiners. The Council requested the Secretary to secure further information relative to one of these applicants, and voted to elect the remaining fourteen.

MEMBERS ELECTED DECEMBER 11, 1908.

ALLEN, THURMAN D., Proprietor, Allen Electric Co., Danville, Ill.

BARKER, CHARLES A., Lamp Agent, Westinghouse Elec. & Mfg. Co., Atlanta, Ga.

BEAUMONT, WALTER W., Asst. Supt., Street Lighting Dept., Equitable Illuminating Gas Light Co., Philadelphia, Pa.

CLARE, CHARLES H., Electrical Engineer, 239 Railway Exchange Bldg., Chicago, Ill.

CLARK, JOHN C. D., Commercial Agent, People's Gas Light & Coke Co., 155 Michigan Ave., Chicago, Ill.

COLEY, CLARENCE S., Supervising Engineer, Douglas Robinson, Charles S. Brown & Co., 146 Broadway, New York.

GROSS, HARRY, Chief Inspector, Street Lighting Dept., United Gas Improvement Co., Philadelphia, Pa.

IRENAEUS, BROTHER, C. S. C., Asso. with Electrical Dept., University of Notre Dame, Notre Dame, Ind.

KELLY, HENRY H., Supt., Gas Dept., Waltham Gas Light Co., Waltham, Mass.

KNIGHT, ARTHUR S., Engineer, Westinghouse Lamp Co., 324 Broad St., Newark, N. J.

LIVOR, HENRY M., Manager, Fixture Dept., Central Electric Co., Chicago, Ill.

SARGENT, FRED H., Assistant Agent, Lawrence Gas Co., Lawrence, Mass.

STEVENS, CHARLES H., Asso. with New Business Dept., Lynn, Gas & Electric Co., Lynn, Mass.

WHITNEY, ROY F., Cashier, Malden & Melrose Gas Light Co., Malden, Mass.

The Secretary reported that five members elected on September 24th, this year, had failed to remit for membership dues.

In accordance with the provision in the By-Laws, the Council cancelled the election of these members.

The General Board of Examiners reported that applications for membership were frequently received which failed to give complete information regarding the applicant's occupation and com-

pany association. It was suggested that when new application blanks are printed, a space be provided for the additional information required.

NEW ENGLAND SECTION.

A meeting of the New England Section was held on December 3, at which time Mr. Herbert W. Moser presented a paper entitled "The Commercial Illuminating Engineering Division of the Boston Edison Company." There were 31 members present.

NEW YORK SECTION.

Dr. C. P. Steinmetz delivered a lecture on "Illumination and Illuminating Engineer," at the meeting of the New York Section, held on December 10. The lecture dealt with physics and physiology as related to illuminating engineering.

CHICAGO SECTION.

On the occasion of its regular monthly meeting, December 10, the Chicago Section was the guest of the National Commercial Gas Association at the First Regiment Armory where a gas appliance exhibition was being held. An address was made by Mr. Cressy Morrison on "Advance in the Gas Lighting Industry." It is expected that this meeting will result in an increased interest on the part of the gas men in the affairs of the Society.

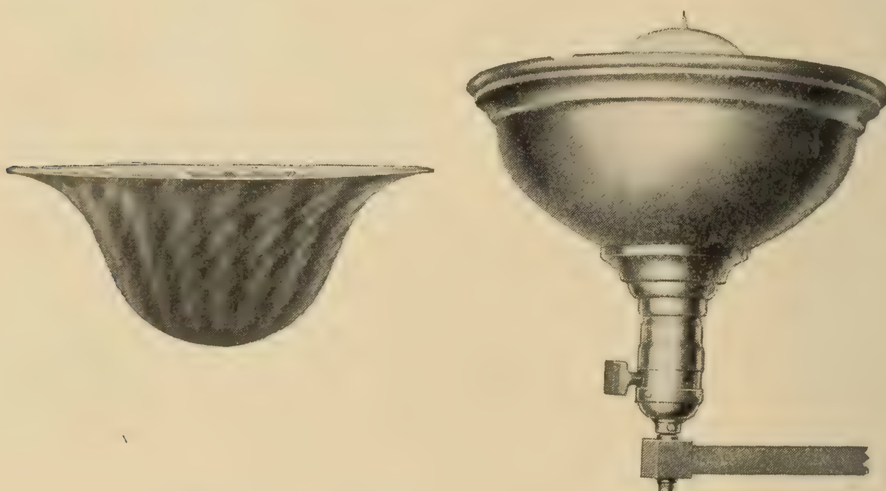
PHILADELPHIA SECTION.

At the meeting of the Philadelphia Section held on December 18, the subject of "Indirect Illumination" was discussed, demonstration being made of the indirect system of lighting. Commercial applications of the illuminometer were demonstrated by Messrs. Bond and Bartlett.

INDIRECT ILLUMINATION.[1]

BY AUGUSTUS D. CURTIS AND A. J. MORGAN.

The term indirect illumination is usually employed to designate that form of artificial lighting which depends upon reflections from ceiling, walls or other surfaces, the source of light being concealed. It has been recognized that indirect illumination is excellent from the standpoint of eye-comfort, but the system has been considered too expensive and inefficient in operation to be feasible for common use. The present paper contains a discus-



Figs. 1 and 2.—Reflector and one-unit adaptable.

sion of a system of indirect lighting which is believed to be both practical and economical.

The prime requisites for an indirect-lighting system are low-priced high-efficiency lamps, and reflecting surfaces having low absorption. When gas is used a satisfactory lamp is the high-grade incandescent-mantle burner. When electricity is employed the tungsten lamp proves excellent for the source of light.

The character of the reflector employed has a vital influence on the results. The necessity for efficiency and durability is evident. It is equally important for the reflector material to be

[1] A paper read before the Chicago Section of the Illuminating Engineering Society on October 15, 1908.

capable of being moulded so that the output may be uniform and correct in design. The reflector should be so arranged as to permit of easy and thorough cleaning, and the shape should be such as to produce the desired illuminating effects in the room.

The reflector selected is of an inverted bell shape, containing circular and vertical corrugations which throws the rays of light to the ceiling without shadows. The reflector consists of a single piece of blown glass coated on the outside with pure

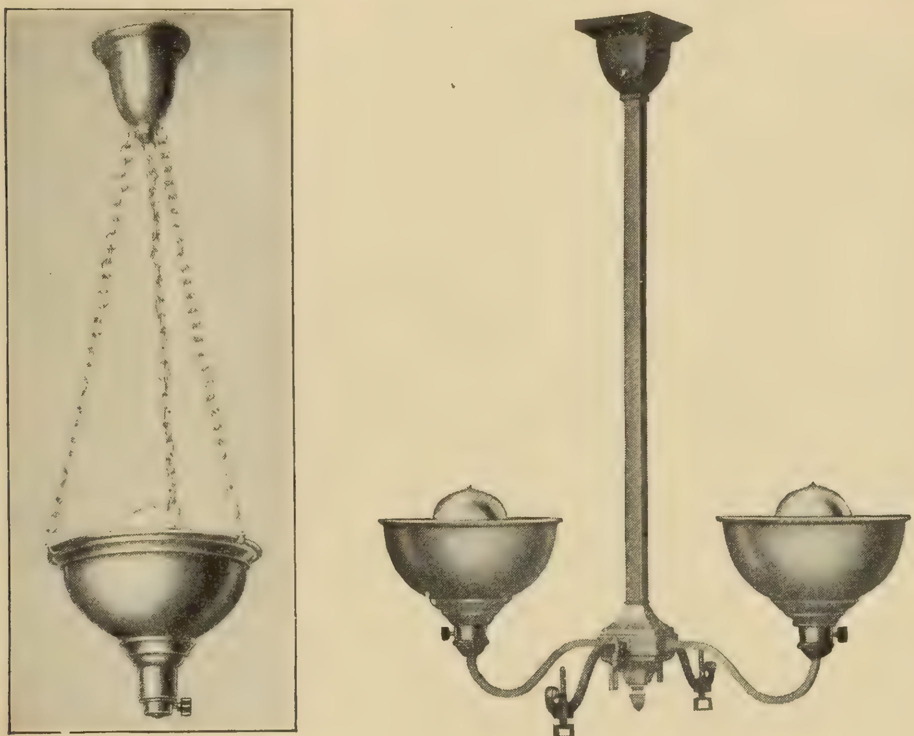


Fig. 3 and 4.—One unit chain, and two-unit electric fixture with gas outlets.

silver, the reflecting surface being of high efficiency. This same general type of reflector has been in use for several years.

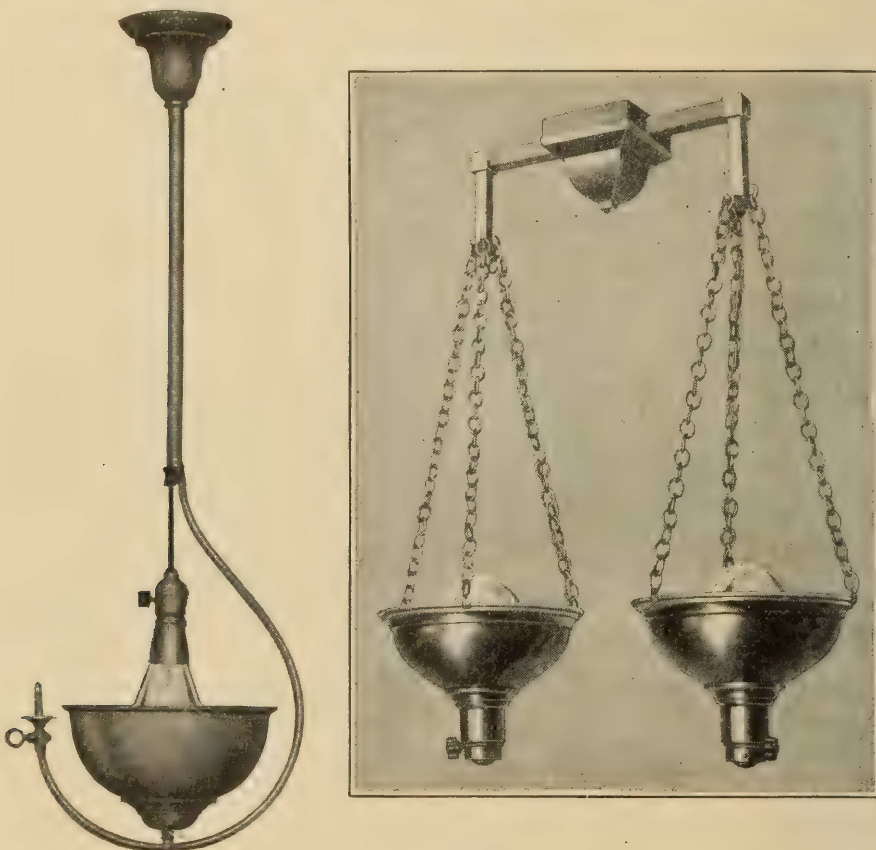
The bell-shaped reflector is fitted into a spun-brass casing. On gas fixtures the casing rests on the base of the mantle burner like a globe. On electric fixtures the casing can either be suspended by chains or supported from below.

The arrangement described above can easily be adapted to old chandeliers. Unless the chandelier arms are very heavy, it can be applied to any electric chandelier where the sockets are pendent, because the arms do not cast annoying shadows on

the ceiling; the light comes from many directions when passing the arms, due to the corrugations.

The lighting unit should be at, or near, the center of the room, though side lamps have been used with satisfactory results. It is not essential for the walls to be light colored, as most of the light is directed to the ceiling.

While it is true that there is a loss of light in indirect as com-



Figs. 5 and 6.—Combination gas and electric fixture lamp pendent and two unit chain electric tip upright.

pared with direct illumination, another factor enters to overbalance the loss. The more easily details can be seen the more effective is the illumination. When there is a bright naked lamp in front of the eye, the pupil contracts and therefore the eye takes in less of the light and the things that are illuminated are not seen as clearly as they are with less light and a wide-open pupil. Hence the fact that there may be less light with indirect illumination does not necessarily mean that one sees less clearly; on the contrary, he really sees better.

Of course, the system of illumination described herein, is not entirely practical with beamed ceilings or those of dark tint, but in the majority of instances the ceilings are light and the conditions are favorable. There are at present about fifteen experimental installations of the system in use among professional and business men in their residences and offices in this city. Without exception the users are enthusiastic in its praise, and are impressed with the eye-comfort derived by its use.

Fig. 7.—Illumination of a 12 x 14 room with a 60-watt tungsten unit.

The lighting units can be arranged in a variety of ways. The fixtures can be installed in single units, or multiples thereof, either electric, gas or combinations of both and it is practical to illuminate in this way, not only residences, but halls and auditoriums.

A unit of one reflector and one 100-watt tungsten lamp (about one-half watt per square foot) or a good gas mantle burner (consuming about 4½ cubic feet per hour) gives adequate illumi-

nation in a room up to 15 feet square. The low consumption makes the cost very reasonable.

It is a peculiar fact that the impression formed by almost anyone coming unexpected for the first time into a room illuminated by the indirect method of lighting is rather likely to be adverse if any thought is given to the lighting at the time of entering the room. A great many—in fact a majority—do not at first note anything out of the way or unusual in the lighting of the room, and sometimes an hour may elapse before the subject is mentioned. Many feel lost without a source of light in full view, and the almost universal first opinion, when thought is given to the lighting, is that the lighting is insufficient. This opinion is almost always changed within a very few moments, and an experience of an hour or at most two hours means a convert to the indirect system of lighting.

The authors are indebted for valuable suggestions to members of the Illuminating Engineering Society and also to members of the Chicago Opthamological Society who have attended meetings of the former Society and who were emphatic in the assertion that many eye troubles are caused by the present method of artificial illumination in which the delicate mechanisms and nerves of the eye are subjected to the direct rays of the intensely brilliant modern lighting units. Mr. J. R. Cravath acted as consulting illuminating engineer in connection with the design of the reflector and the technical points involved.

DISCUSSION BY THE CHICAGO SECTION.

Mr. J. R. Cravath:—Heretofore, indirect lighting systems have usually been failures in the long run for a number of reasons, the principle ones being dirt and inefficiency of reflection. Some of these reasons were not understood until illuminating problems were studied in a scientific way. The indirect lighting system described in the paper owes its efficiency, aside from any question of lamp and reflector efficiency, to the fact that the greater portion of the light is directed towards the central part of the ceiling so that it has to undergo only one reflection before it reaches the useful or working plane. This is not the case in a number of previous attempts at indirect illumination, particularly in cove lighting, which appears to have been unsatisfac-

tory except for occasional show purposes. With that system of illumination the light strikes the ceiling at a very oblique angle and is reflected back and forth between the side walls many times before it finally reaches the working plane so that there has been a large loss by absorption. In a few of the more recently designed cove lighting systems this has been avoided by building the reflecting surface on the ceiling of such shape that the light from the cove is reflected mainly downward rather than sideways. If dependence were placed on the light reflected from the lower portion of the walls to a great extent the indirect system of illumination shown would be of very limited application, especially in a city where people are apt to select dark tints. However, in the majority of cases the ceilings and walls are light, as Messrs. Morgan and Curtis have explained, so that indirect systems of illumination of the kind can be used very satisfactorily. In working out a design of reflector for this purpose it was considered necessary to reflect most of the light to the ceiling in the center of the room and still get enough in the corners of the average room so that they would not appear dark. Of course in small rooms the light might well be more concentrated near the center of the ceiling but it was necessary to consider illuminating both large and small rooms satisfactorily with the same kind of a reflector. The reflector is, therefore, a compromise between the reflectors for large and for small rooms.

I think there is no doubt that indirect illumination with side walls not too highly illuminated is more comfortable in every way than direct illumination. One of the things noticeable about this system is the absence of the glare from highly sized paper. Nearly all papers and books are so glazed that they are good reflectors, but with the indirect system the light comes from a large area overhead so that reflection does not bother one.

Another interesting point about indirect illumination is the possibility of reducing the number of outlets in a room, and thereby reducing the cost of wiring. With direct illumination, especially in a bed room, there should be one central lamp for general illumination, one on each side of the dresser for use there, and one near the bed for reading. The expense of wir-

ing is so high that the majority of people get along with one central outlet and very indifferent illumination. With indirect illumination the whole room is well lighted, possibly at a little more expense for energy, but most people would be willing to spend more for energy in order to save in the first cost of wiring. However, a bed room must have very light walls to be satisfactorily illuminated with indirect lighting in the middle.

Mr. V. R. Lansingh:—The effect which these gentlemen have so well accomplished is, of course, not new, but it has never previously been put in practice so successfully. In the case of some of the New York City Hospitals use is made of the indirect lighting system by means of central chandeliers for the wards. At first use was made of a large brass shade. somewhat similar to these, the lamp being placed inside in any position; the inside was of polished metal with no protection whatever to prevent the dust from falling inside. In some of the more recent cases reflectors have been placed inside of the bowl and a thin glass plate is used to protect the fixture from dust. The illumination obtained was very pleasant and effective.

One of the most notable examples of indirect illumination has been in the Harlem Office of the New York Edison Company. In a room about 100 ft. long with a very high ceiling, the walls and ceiling being in light colors, the illumination was very high in foot-candles but the effect was too trying on the eye. It seemed from the experience with light walls and ceiling that there was no place where the eye could rest. The installation was changed somewhat by combining direct and indirect illumination, and the effect was very beautiful as well as restful to the eye. I believe that trouble would not have occurred with dark walls. With indirect illumination one must darken the walls and sacrifice some of the efficiency.

From looking around the bed rooms here, and other experiences I have had, I believe that satisfactory illumination can not be obtained on the dresser without having one small lamp on either side of the dresser. I believe that the individual lamps combined with the indirect lighting equipment can not be excelled.

Prof. Morgan Brooks:—I might suggest that a light border near the top of the wall, with the balance of the wall dark would allow the eye to rest properly. The system of indirect illumination described seems very beautiful, and the success already attained in the design of the fixtures seems very commendable, although some arrangement should be made to unhang the bowl in order to clean it properly.

Mr. Albert Scheible:—Are the corrugations put in the reflector merely for mechanical reasons or have they some value in increasing the distributing efficiency?

Mr. Cravath:—They are used to avoid streaks on the ceiling The question has been brought up of light walls and ceilings having the effect of tiring the eye. In a system of illumination where a large flux of light is being directed towards the walls, and where the walls are very light, is indeed very trying to the eye. Where most of the light is directed to the ceiling, and where the walls are not lighter in color than they are ordinarily, I think the illumination is not trying to the eye.

Mr. G. H. Jones:—I think the fixtures described should prove very satisfactory if used properly. In designing a system of this kind I believe it would be necessary to place a number of outlets in the side walls, as small portable lamps are very home-like. One central fixture for the general illumination, with outlets for decorative lighting or reading lamps would seem to me the more desirable arrangement.

Mr. Cravath:—I think it is not desirable to eliminate the shadows entirely. I believe one of the things that has been urged against indirect lighting as it has frequently been carried out is that the shadows are so nearly eliminated that things do not look natural. Shadows are given by daylight, and I think there should be a few with artificial lighting.

Mr. Wiley:—Would not gas and other things have a tendency to tarnish the reflector as well as the shade?

Mr. Curtis:—We purposely refrained from going into the commercial end of the proposition in our paper. The mirror plating is of pure silver, the application of which is a trade secret. Before I became interested in the company making these reflectors I investigated that point very thoroughly, and

found that a man had spent six years in perfecting the process and the application of an elastic substance that would expand and contract with the glass when heated and cooled without breaking the glass or tarnishing. The surface of the reflector is very smooth, being almost like polished plate glass. The hole at the bottom of the reflector was left purposely to take care of the larger particles of dirt and allow them to settle into the brass bowl underneath, and also for the purpose of ventilation. Most of the lamps that are illustrated are suspended with the point of the tungsten lamp downward. The lamp manufacturers, as I understand it, expect to perfect the lamp so that it can be used with the point upwards. When the lamps can be used successfully with the tip upwards the fixture becomes simplified.

Mr. Geo. Loring:—There is no reason why a 40-watt tungsten lamp cannot be used as successfully with the tip up as in any other position. I believe that this remark will not apply to the 25-watt lamp at the present time. However, I believe, that a unit smaller than the 40-watt lamp will not be used in indirect illumination. When I received word that this system was to be demonstrated I considered it of sufficient importance to justify a trip here from my home in a small City in Ohio. I can say that from the standpoint of comfort and ease on the eye it is certainly a great success. This is the first time for many months that I have been able to sit in a room artificially illuminated without having my eyes troubled unless I turned my back to the source of light. A great many people would notice the lack of glare from lighting units. They would also notice the apparent absence of the light source, and to a large majority of the public who are not giving any attention to illuminating engineering this system would not be pleasant at first, but I believe it is a system that will "wear well."

Dr. Henry Gradle:—The system certainly appeals to any one familiar with the eye. I believe that the closer we imitate the natural light and avoid the glare the better. For instance, if this large picture were lighted in the day time by direct light from the window, it would be poorly illuminated. If the glare were obviated by curtains the picture would appear consider-

ably better. I think this is the point at issue. In the system described a diffused light comes from the entire ceiling, and a sufficient amount of light is thrown on a paper to give a very satisfactory image. We saw the contrast just now when the bowl was removed and the lamp exposed. The total illumination was increased but as measured by the ability of the eye to read with comfort the change was very unpleasant.

Mr. Pond:—I have been impressed very favorably with the various possibilities which seem to present themselves with this system of lighting. We who have sensitive eyes have been able to sit here this evening and read the fine print at various angles, and do so with comfort. It is almost impossible to obtain such a result with any system of light from a direct source.

Mr. White:—The light here to-night seems very pleasant indeed. I think there is no question as to the practicability of this lighting system and the advantages of it. It is necessary merely to convince people that these reflectors can be easily handled, and easily cleaned, and I have no doubt about their permanency. The cleaning is the more necessary feature to consider. The smooth surface of these reflectors will collect exactly the same amount of dirt that collects on plate glass windows. Since windows should be washed once a week in a City like Chicago, I should imagine that these reflectors would require the same attention.

DISCUSSION BY THE PHILADELPHIA SECTION.

Mr. H. Calvert:—The library room in this building measures 26 ft. x 27 ft. x 26 ft. high, and in it have been installed four one-unit fixtures of the type described in the paper. The fixtures which belong in the room consist of four prismatic cluster arrangements having a total rated candle-power of 960 and consuming 2400 watts. Each of the four indirect lighting fixtures contains one 100-watt tungsten lamp—hence the total consumption is 400 watts and the total rated candle-power 320. The value of watts per square foot with the clusters is 3.43, and 0.57 with the indirect lighting equipment. Photometric readings taken on a table at the center of the room, on a table under the fixtures and on a window sill at the center of the

side of the room gave values of 3.5, 4.7 and 3.1 (3.8 average) ft.-candles respectively for the cluster lamps and 0.69, 0.66, and 0.42 (0.61 average) ft.-candles for the indirect lighting equipment, all of the lamps being 13 feet above the floor. When the lamps in the indirect system were placed 24 feet above the floor the readings were 0.88, 0.73, and 0.64 (0.71 average) ft.-candles, the average illumination being increased 0.1 ft.-candle by the change.

Mr. W. A. Evans:—Some recent tests conducted by me relating to the effect of color and diffusion of light upon the required density of illumination may be of interest. The color of light obtained from mercury-vapor lamps used in combination with tungsten lamps was found to be closely that of diffused daylight; the color was of the order of a robin's egg blue, whereas daylight was somewhat bluer. A density of from 1.5 to 2.0 ft.-candles was sufficient for all accounting purposes, although with ordinary artificial light from 4.0 to 5.0 ft.-candles would be required. Observation showed also that when a tungsten lamp with a frosted prismatic reflector giving an illumination of 8.0 ft.-candles was turned towards the ceiling the illumination was decreased to 2 ft.-candles, and even to 1.5 ft.-candles when the light source was hidden from view, and yet one could read with more comfort under the decreased illumination than formerly. It would seem from these tests that there are three factors which determine the amount of light required for reading purposes. The first is the color; the second is the diffusion and the third is the hiding of the source of light. By taking advantage of all of these factors one is enabled to reduce the cost of producing satisfactory illumination for specific purposes.

Mr. P. H. Bartlett:—Each of the fixtures used in the library contains only one 100-watt tungsten lamp, and it is probable that the designers of the system described in the paper would not be satisfied with the total amount of candle-power used in so large a room.

Mr. C. O. Bond:—The system of indirect illumination from the ceiling has been tried before, arc lamps being used, but it proved a total failure. Probably much of the trouble was

due to the unsteadiness of the light which the eye attempted to follow. In the system described in the paper the light is steady and the eye experiences a feeling of restfulness rather than one of discomfort when the light flickers.

Mr. Toerring:—The remarks concerning the arc lamps are unfair. As a matter of fact arc lamps have been installed on two floors of the Curtis Publishing Company's building over the desks that are used by the subscription clerks and they have proved satisfactory with reference to comfort of the eye. Moreover, they permit one to see the bottom of a deep card index box and read the names on the cards without encountering annoying shadows. In indirect lighting the direct-current arc lamp possesses an advantage over the alternating-current arc lamp in that by placing the positive electrode at the bottom 85 per cent. of the light is thrown directly to the ceiling without previous reflection and absorption. Furthermore, it is possible to distinguish shades of colors by indirect arc lighting equally as well as by daylight.

Mr. Norman Macbeth:—In considering the system, described in the paper it seems to me that the comparison should not be made with diffused arc lighting systems, but with the older method of indirect lighting, namely cove lighting. The theory of this method of indirect lighting may be good, it may conform to all the demands of the aesthetic, but in practice it has rarely been satisfactory.

The similarity of the systems described and cove lighting seems to be borne out even in its inefficiency. I am of the opinion that the calculated results given by Mr. Calvert, especially with the direct lighting system regularly used in this room, are not such that any certain value can be attached to them. Taking three readings, one in the center of the room, one under a cluster and another on a window-sill, will not give results from which one can state the average ft.-candles on the plane in a room having an area of over 700 sq. feet. By noting the wattage per square foot 0.57 for the indirect and 3.43 for Gem (or an equivalent in tungsten of 1.71) for the direct lighting, and accepting the average foot-candles given, 3.8 for the direct and .71 for the indirect, it would seem that

the efficiency of the indirect was about 57 per cent. of that of the direct lighting.

Reference can be made to two papers given in the Society *Transactions,* one by Mr. Edward A. Norman in 1907, and another by Mr. Preston S. Millar at the Boston Convention in 1907, on indirect methods of illumination. The values given are somewhat similar in result to the values secured here.

In the New York Edison Harlem office as reported by Mr. Norman, the efficiency of the cove or indirect lighting was just over 46 per cent. of that of the direct system. The theory and effect of cove and indirect methods of illumination has been endorsed by many authorities and a great deal has been said in favor of these systems; nevertheless very few people seem to be satisfied with the results. I do not know whether it is because of an apparent lack of the aesthetic temperament or a failure on the part of these systems to deliver practically what may seem good theoretically. I believe that the kind of diffused lighting characterized as shadowless can not be good, because the absence of shadows is neither natural nor desirable.

In the paper reported by Mr. Millar the diffused lighting system showed only 28 per cent. of the illumination of the direct lighting system effective on the plane. The absorption by the first reflecting surface was not so much responsible for this low figure as was the method itself, large losses being due to multiple diffuse reflection and the ineffectiveness of rays falling at small inclinations upon the surface to be illuminated. It was found in a test reported by Mr. Millar that on a placard on the wall, when viewed at a distance of eight or ten feet, thirty times as much light was required to enable an observer to read as well with the indirect as with the direct lighting system. This result was due to pupilary contraction caused by the brilliantly illuminated walls under the indirect system.

A test was also made at that time with a number of different observers who were allowed to specify the amount of illumination they desired for reading both with the direct and the indirect systems. The results showed a demand for 65 per cent higher intensity by diffuse lighting than by the direct.

The cove lighting in the Edison Auditorium was found to be objectionable to members of this Society when the New York Section meetings were held in that room. When attention was called to it, the front section and part, if not all, of the side lamps were cut off during the time of the meetings.

I have gone over a number of reports and also installations of cove lighting and am unable to find or hear anything but adverse criticism, not only on the ground of inefficiency, but also because the method is not satisfactory.

With the system described in the paper it would seem that considerable difficulty would be experienced because of dust. If direct lighting systems, where the lamps and shades are in plain view and within easy reach, are permitted to deteriorate 30 per cent. through accumulations of dust, one may expect a greater deterioration from a system where the condition of lamps and reflecting surfaces is not so readily apparent.

Mr. Bartlett:—The values given by Mr. Calvert are not directly comparable. The prismatic clusters are suspended 13 ft. from the floor, whereas the ceiling which is used in the indirect lighting equipment is 26 ft. The comparison would be much more fair if the ceiling were considerably lower.

Mr. Calvert:—On account of the fact that the prismatic clusters are equipped with 2.5-watt lamps while the indirect lighting fixtures are provided with 1.25-watt lamps, the systems cannot be directly compared on a basis of watts per sq. ft.

Mr. Bond:—It should be noted that the system described in the paper differs from the cove lighting system in that in the latter the illuminated area is always at the extreme edge of the ceiling, and is visible from all positions in the room, while in the former no tangible source of illumination is presented to the eye.

Mr. Simmonds:—The cove system of indirect lighting is being used with success for church lighting at Mauch Chunk, Penn. On either side of a church having a floor area of 50 ft. by 75 ft. there are two lines of straight filament 16-cp. tubular incandescent lamps, 69 in number, placed in coves 24 ft. from the floor, the light being directed to an arched ceiling 35 ft. high

in the center. The illumination is very satisfactory to every one.

Mr. R. C. Ely:—In the system described the efficiency would probably decrease rapidly due to the collection of dust. The closer the fixtures are placed to the ceiling the better is the illumination, but the more difficult is the cleaning process. The lowest intensity of illumination appears to be directly under the lamp, hence the system seems not to be applicable to a dining room where high intensity is desired on the table.

Mr. Calvert:—In the room containing four fixtures, the intensity was observed to be greater in the center of the room than directly under any one fixture. Just what the result would be in a smaller room with one fixture in the center, it is difficult to predict, but the reflections from light side walls might increase the light under the fixture.

Mr. F. N. Morton:—About twelve years ago I tried a series of experiments with diffused lighting and lighting by transmission, the results showing that reflected light is very tiring to the eyes, while the light passed through a surface such as an opal globe is most restful to the eyes.

Mr. Saunders:—About ten years ago Prof. Elmer Gates came to the conclusion that the trouble with reflected light is caused by polarization, and in order to avoid polarization he employed a matted surface using pigments and chemicals on the reflecting surfaces. He claims to have made a distinct gain in efficiency by changing the wave length of the light, the violet and ultra-violet rays being changed to the other end of the spectrum. I understand that Prof. Gates has collected a large amount of data but has not published the results of his observations.

ILLUMINATION OF THE OFFICE BUILDING OF THE PHILADELPHIA ELECTRIC COMPANY.[1]

BY P. H. BARTLETT.

The building of the Philadelphia Electric Company, located at Tenth and Chestnut Streets, was completed in the Spring of 1907 and was especially designed to serve as a general office building for the Company, the possible requirements of the Company and developments of the business for a number of years to come being taken into consideration. The building consisted of seven stories and a basement; it has a frontage of 32 feet on Chestnut and Sanson Streets, 229 feet on Tenth Street and rises to a height of 105 feet.

The main entrance of the building is on Chestnut Street with a side entrance on Tenth Street generally used for lamp exchange purposes, and a rear freight entrance on Sanson Street. The entire Chestnut Street front of the first floor and a depth of 80 feet on Tenth Street is composed of glass, leaving the entire display room open to view from the street and permitting the entrance of a flood of natural light during the day time and the exit of a flood of artificial light at night.

The basement of the building contains an exhibition room, a dark room, mechanical plant, lamp and stationery storage, locker and toilet rooms, etc.

The front part of the first floor is used as a display room and the rear is devoted to general office purposes. The second, third, fourth and fifth floors are occupied by general offices and the sixth floor contains the library, Assembly and committee rooms and draughting room.

It is obvious that the building, fronting on three streets, obtains an ideal daylight illumination, while even the basement receives a certain amount of illumination through the medium of a white-enamel brick-lined area-way covered with an iron grating and extending along the entire Tenth Street front.

[1] A paper presented at a meeting of the Philadelphia Section of the Illuminating Engineering Society November 20, 1908.

Under these conditions, artificial illumination, is generally speaking, required only on dark days or towards evening. There are, of course, exceptions in some few cases where offices are partitioned North and South and where men are working at desks located towards the West wall and away from the source of light.

As light might be termed one of the principal stocks in trade of the company, the artificial illumination of the building naturally received careful attention and consideration from the officials and engineers of the company. This question was a rather more complicated problem than is encountered in the lighting of the ordinary office building as the offices are irregular in size and many of the rooms are used for more or less special purposes, requiring more or less special treatment.

The general idea of introducing as many different methods of lighting consistent with certain standard of efficiency was followed, making the entire illumination of the building more or less an exhibition of such methods, which are fair examples of methods in which customers are likely to be interested.

The installation of different systems throughout the building was necessary as it was undesirable, from an artistic standpoint, to have more than two different systems of illumination in the first floor display room and the ceiling of the basement display room was too low to permit of any lighting except by the scheme later described.

A room lit by a certain type of lamp and fixture in this building would not, of course, be fully indicative of the effects to be obtained with the same outfit in another room of different dimensions and wall finishings, but anyone not familiar with the different types can get a fair general idea of effects and efficiencies.

Another phase of the situation which had to be taken into consideration was the promised rapid development of higher efficiency units of different types and it was necessary so to arrange the outlets that the more efficient units could be installed in certain parts of the building without disturbing the general distribution. It was with these ideas in mind that the illumination was originally planned. The ceilings, with the excep-

tion of the basement, being all over 11.5 ft. permitted a wide range in variety, including cornice lighting, different types of fixture lighting, ceilings studded with lamps, cluster lamps, concentric diffuser arc lamps, bracket lighting, etc. Many different types of lamps were used, including carbon and round bulb frosted incandescent lamps of different candle-powers, high efficiency tantalum, tungsten and Nernst lamps.

Endeavor was made to shield all of the light sources from the eye by either using frosted tip or in some instances all frosted lamps, or the proper type of shades and to provide, as far as possible, general illumination of sufficient intensity to render individual desk lighting unnecessary. In actual practice, however, it is questionable whether this is economical as the alteration of the position of a desk or table and the personal desires of the different men have to be reckoned with.

Furthermore, on a dark day or when only one man may be at work in an office, a single desk lamp, if available may be sufficient, whereas if no provision has been made for localized lighting, part or all of the entire room must be illuminated. In the private offices, therefore, and in general offices where the men were apt to be more or less in or out during the day, a sufficient number of flush receptacles were installed to permit of individual desk lighting.

The illumination figured on varied from 0.5 to 3.0 or more foot-candles, depending on the location; the general office lighting being figured for from 2 to 3 foot-candles.

The building has been wired for three-wire 110-220 volts direct-current service, and alternating-current service has also been introduced, furnishing single-phase and two-phase 110-220 volts for use in the display room, dark rooms, and for experimental and lecture purposes in the assembly room.

The building is wired in conduit and the construction rendered it necessary to provide outlets for every contingency, as there are no hollow partitions or spaces between floors and ceilings, and any additions consequently have to be made with some form of exposed work.

The energy for the general lighting of the building is supplied from three vertical mains extending from the main switch-

board located near the center of the Tenth Street front to the seventh floor level. These mains pass through a panel board on each floor, from which the circuits for only the particular floor were run. A number of additional mains were installed for display room lighting, exhibits, motors and signs, some of these being subdivided to permit of separate metering.

There was a certain uniformity in the spacing of the outlets, this being due to the general dimensions of the rooms and the location of the partitions; this condition will readily permit, by the application of proper units and shades, the changing of the lighting in any room. The majority of the outlets are controlled by separate switches, the only exceptions being made in a few of the larger rooms where two outlets are controlled by a single switch. All of the switches are placed at the doorways, and when an office has more than two outlets and two entrances a switch is placed at each door.

No special difficulties were encountered in the construction work, with the exception of details such as doors being hung differently than originally proposed which placed the switches in a few cases on the wrong side of the door. The outlets were installed on certain centers regardless of the position of beams, resulting in some of the fixtures hanging close to a beam, while others were more or less centrally located between beams. It is believed that the general appearance, in some instances, would have been improved by slightly increasing or decreasing the distance between outlets and permitting all of them to be placed centrally between beams.

Most of the panel boards used throughout the building are of the plug fuse type, with polished copper finish on black enameled slate. The panel controlling the basement display room lighting circuits is one of the exceptions, this having push button switches in the metal trim of the panel. The panel boards in the first floor display room are exceptions and are also worthy of mention, being of the ordinary knife switch and enclosed fuse type, but illustrating, with their marble and gold finished metal trims, that a panel board can be made ornamental as well as useful.

In the basement display room, which has a low ceiling—

only 9 ft.—and where a good general illumination was desired, the paneled ceiling was studded with 16-cp. round bulb frosted lamps so arranged that each panel may be lighted separately. These lamps are placed on from 6-ft. to 8-ft. centres depending on the paneling. The outlets are furnished with a spun brass canopy and the receptacles are mounted in the outlet box permitting the lamps to hang close against the ceiling. This arrangement gives a uniform illumination of 0.9 ft.-candle on the floor at an expenditure of 1.09 watts per sq. ft. The illumination might possibly be increased somewhat by the use of diffusing shades and frosted tip lamps, but as the ceiling is white, affording a good reflecting surface, the increased efficiency to be obtained by the shades was sacrificed to appearance.

The capitols of the two columns in the meeting room are equipped with bands of 16-cp. round bulb frosted lamps of standard size. The column lighting was not designed, however, for use in conjunction with the ceiling lighting, but was installed to demonstrate this form of lighting to those interested and also to furnish a certain amount of general illumination to the room at such times as the ceiling lighting was unnecessary. The column lighting is used frequently on account of its decorative effect, and of the possibilities it presents of eliminating fixtures. To make this lighting artistic, however, the lamps must be placed as close together as mechanical conditions will permit.

The dark room in the front basement is illuminated from three ceiling outlets, controlled by three-way switches, one located at the door and one located at the instrument table. The largest of these rooms has been equipped with a standard photometer, and the necessary instruments, and direct and alternating current and also gas are available at this point. This room also contains two booths fitted with ceiling outlets and adjustable bar outlets for comparisons of lamps and shades. The smaller room is equipped with a number of color boxes for illustrating in a crude manner the effect of different colored walls on illumination, and there are also three small booths containing respectively, an arc, Nernst, and different incandescent lamps, for making comparisons of the effect of differ-

ent illuminants on the same colors. A fairly complete list of of different types of shades and lamps completes the equipment of these rooms. The balance of the basement, consisting of the mailing department, mechanical plant room, lamp storage, locker rooms, etc., is lit with individual high efficiency units.

The first floor display room is illuminated by four specially designed 25-lamps Italian Renaissance electroliers, each controlled by two switches. The use of these fixtures was especially desired by the architect as a finish to this room, and they are excellent examples of an artistic fixture designed exclusively for electric light work. They were designed originally for round bulb frosted lamps, from which fairly good results were obtained, but the outer row of these lamps was later removed and adapters with 40-watt tungsten lamps and shades were installed, which, while they detract somewhat from the general appearance of the fixtures, are naturally much more efficient and permit the display of tungsten lighting in this room. The room is also illuminated by 178 round bulb 16-cp. frosted lamps located in the soffit panels of the planacea between the modillion brackets of the Corinthian cornice. These lamps are controlled by two switches, permitting the lighting of every other lamp or the entire number, as may be desired. The fixtures and the cornice work provide two distinct systems of lighting in this room, the fixtures giving an average illumination of 4.5 ft.-candles on the floor and the cornice an average of 2.1 ft.-candles, this latter being very uniform. The cornice lighting is not, of course, an efficient form of lighting, but is decorative and makes a soft and pleasing illumination.

The lighting of the windows in the display room was given some little thought, it being at first considered that as the windows were open to the room and the room brilliantly illuminated, the window lighting would perhaps be unnecessary. Owing to the construction of the windows, it also seemed impossible at first to provide any means of lighting that would not be visible either from the inside or outside. It was finally decided, however, to install a mirror window reflector of a slightly different design from the standard in the hollow transom bar between the upper and lower sections of glass, thus making a

practically concealed form of lighting, and giving an average illumination of 11.6 ft.-candles on the floor of the windows, the measurements being taken without any other lighting in the room. The lighting of the cashier and stock transfer offices, which are located at the rear end of this display room and are surrounded by 7.5 ft. curved wood and glass partitions, was also the subject of some thought, as the offices could not be lit from the ceiling, and it was necessary to furnish a certain amount of illumination directly on the desks without depending upon the general illumination of the room. The desired result was finally obtained by installing 16-cp. lamps in a horizontal position around the inside of the top of the partitions, supplemented by special wall brackets on the side walls. The partition outlets are equipped with a husk, canopy and green half glass shades, the side brackets being equipped with prismatic reflector globes and those over the desks with green glass cone shades.

Each of the two small offices immediately in the rear of these rooms, and which are also in the display room and surrounded with wood and glass partitions, was lit with three 2-lamp side brackets equipped with prismatic reflector globes, the glassware being especially designed for side wall brackets and having the reflecting prisms on the wall side and diffusing on the other. The average illumination in these rooms is 2.7 ft.-candles, with an expenditure of 2.86 watts per sq. ft.

The small offices located south of the display room partition are approximately 10 ft. x 10 ft. or 10 ft. x 20 ft. and each 10 ft. section is illuminated by a 6-lamp prismatic cluster suspended 8.5 ft. from the floor and equipped with 20-cp. tantalum lamps. The same scheme of lighting is carried throughout the balance of the first floor with the exception of the rear entrance passageway, which are lit with single high efficiency lamps hung at the same level as the clusters.

The solicitors' room on the second floor, having dimensions of 56 ft. x 20 ft. is illuminated with ten 2-glower Nernst lamps equipped with prismatic hemispheres. These lamps are installed in a double row on 11.5 ft. centres at a clear height of 11.3 ft.

and give an average illumination of 2.5 ft.-candles for 1.69 watts per sq. ft.

The paymaster's office on this floor is illuminated by six high-efficiency lamps suspended 11.3 from the floor and equipped with reflectors. The area illuminated is 850 sq. ft. with an expenditure of 1.77 watts per sq. ft. and an average illumination of 2.1 ft.-candles.

The private offices throughout the building are, with few exceptions, illuminated by 3-lamp, 4-lamp and 5-lamp fixtures of a standard design hung 8 ft. from the floor to the under side of the lamps and equipped with 16-cp. frosted tip lamps and prismatic shades, the average illumination being 2.5 ft.-candles.

The general office on the third floor is illuminated with six lamps with bowl-type prismatic reflectors. This room is 15.5 ft. x 21.5 ft. requiring 1.5 watts per sq. ft. with an intensity of illumination equal to 2.4 ft.-candles. The two rear rooms on this floor are illuminated with 4-lamp and 6-lamp prismatic clusters equipped with 16-cp. frosted-tip lamps, giving an average intensity of 3.1 ft.-candles.

The accounting department on the fourth floor, a room 105 ft. long and 27 ft. wide, presented a difficult problem. The high desks in this room were arranged in rows East and West, leaving a passageway about 6 ft. wide along the West wall. The purpose for which the room was to be used required good illuminations so obtained that there would be as little reflection as possible from the ledgers and other books in constant use, and also no shadows on the books. As originally laid out and equipped, this room had 16 6-lamp clusters with 16-cp. frosted lamps, and incandescent diffusers for general illumination, and receptacles were provided at the end of each row of desks to permit of some individual form of desk lighting where necessary. It was found, however, that any form of desk lighting not located above and behind the individual was objectionable on account of the reflection from the paper and also on account of the desk fixtures interfering with the opening and closing of the books. As the desk lighting involved either hanging additional lamps from the ceiling for which outlets were not provided, or installing a type of desk fixture which presented

certain mechanical difficulties, the scheme was abandoned. Furthermore, while the incandescent diffuser clusters were installed close to the ceiling, the length of the room brought them well within the line of vision and the whole installation was more or less objectionable. A short time ago the lighting of this room was re-designed, and as now installed there are 192 20-cp. lamps arranged in rows of eight on the South vertical side of the ceiling beams, this being the direction in which all of the men face. These lamps are installed on angle receptacles and equipped with prismatic shades. Four half-rows of these lamps are controlled by a switch, permitting the lighting of sections or the entire West half of the room, which lighting is required more frequently than is the case with the Eastern or window side of the room. The illumination on the working plane averages 8 ft.-candles. The illumination is possibly somewhat higher than is necessary but is extremely pleasing.

In the president's suite in which the ceilings are furred down, some specially designed fixtures were used. In the president's room a dome fixture equipped with a 100-cp. lamp and prismatic hemisphere surrounded by 6 pendants containing 16-cp. round-bulb frosted lamps was installed in the center and four husks and canopies with 50-cp. lamps were installed in the corners. The ceiling of this room is somewhat low for its size, and it was necessary to provide an even illumination and keep the lamps, as far as possible, out of the line of vision.

The library on the sixth floor of the building is equipped with four 6-lamp prismatic clusters having 32-cp. lamps, and a number of flush wall and floor receptacles were installed for reading lamps. The average illumination on a reading plane in this room is 3.36 ft.-candles.

The assembly room on the sixth floor is illuminated with 7.5-amp. arc lamps equipped with concentric diffusers, the body of the lamp passing through the ceiling, allowing the diffuser to bear directly against the ceiling. This form of illumination was made possible by the existence of a loft over the room, from which the lamps may be lowered for trimming. Each of the six lamps used is controlled by a separate switch and is also operated by a solenoid switch controlled by push-buttons

located in different parts of the room. The absence of shadows, a characteristic of this form of illumination, is shown in this room, although the intensity of the illumination, is possibly higher than is necessary for general meeting purposes, the average being 2.31 ft.-candles on a reading plane. This was the only room in the building in which arc lighting could be successfully used.

The draughting room in the rear of the assembly room is lit by lamps with concentric prismatic reflectors placed 30 in. above the drawing boards.

The economical lighting of the halls at a reasonable first cost required consideration, as they are necessarily long and the only daylight received is from the pressed glass windows in the office partitions. The third floor may be taken as representative; in the front hall, four lamps with reflectors are used, and in the center and rear halls lamps with reflectors are installed on approximately 20-in. centers, the front, center, and rear each being controlled by separate switches on each floor. This arrangement provides an illumination of .7 ft.-candle which is more than sufficient for the purpose.

An auxiliary system of night lamps was installed in the form of torch brackets, one at the head and foot of each stairway, and one at the South end of the halls, thus placing three lamps on each floor. These outlets, together with the red exit lamps at the fire tower doors, the lamps on the fire tower balconies and the lamps on each half-pace landing of the fire tower, are controlled from separate panels located in the first floor and basement.

The illumination of the toilets and vaults are hardly worthy of mention, with the exception that the ceiling fixtures and brackets used in the toilets are of plain white enamel finish, and the vault lighting is arranged with the switch-controlled flush receptacle located on the outside at the door of each vault, the connection to the vault wiring being made by a flexible cord which is carried through the vault doorway when open. By this means there can be no circuit in the vault when the door is closed.

No permanent illumination of the exterior of the building

has been provided with the exception of six massive torch form of brackets located on the main piers of the building on the Chestnut and Tenth Street fronts. Each of these brackets contains a 100-cp. tungsten lamp enclosed in a sand blasted globe and might be considered more as an architectural feature of the building than a means of illumination although, of course, it assists in a large measure in brightening up the exterior. A cluster lamp is also suspended from the fire tower balcony on the Sanson Street front of the building for general illumination purposes.

The three-glower Nernst lamps installed around the cornice of the building were part of an exterior decorative scheme installed for some special occasion and were retained semi-permanently as a means of illuminating the upper part of the building. This arrangement proves good advertising and relieves the strong contrast which would exist between the brilliantly lit lower and dark upper part of the building.

Four mains for exterior lighting have been installed from the basement to the roof, and brass capped outlets have been left outside of the building on each floor from each of these mains. Each outlet leads into a cutout panel located immediately inside on each floor, thereby providing an easy method of flooding the exterior of the building with any form of decorative lighting, as many as 3,000 lamps having been installed on different occasions without any feed wires being visible.

Much of the lighting of the building does not, of course, represent the most efficient practice today, and this fact is illustrative of the rapid advances made in the production of the higher efficiency units.

A table showing the illumination data in a number of the rooms is appended.

Location	Lighting installation	Height of lamp	Condition	Area sq. ft.	Watts	Average foot-candles	Watts per sq. ft.	Foot-candles for 1 watt per sq. ft.	Plane of illumination
Basement display room......	37 16-cp. ceil. lamp	9′ 0″	Ceil. lamps alone	1700	1850	.9	1.09	.82	On floor
	20 16-cp. column lamp		All lamps	1700	2850	1.3	1.67	.78	
First floor display room.....	4 13-lamp chan. 40-watt tungsten	11′ 6″	Chandeliers alone	2292	2085	4.5	.91	4.95	On floor
	178 16-cp. cornice	22′	Cornice lamps "	2292	8900	2.1	3.90	.54	On floor
			All lamps	2292	10985	6.6	4.79	1.38	On floor
Show windows, first floor....	Mirror ref. 50-watt Gem lamp every 1 ft.	10′	All lamps	280	5000	11.6	17.85	.65	On floor
Waiting room, first floor	3 2-lamp brackets	6′ 6″	All lamps	105	300	2.7	2.86	.94	On table
Room 201, office............	1 4-lamp chand. 40-w. tan. 2 1-lamp brkts. 40-w. tan.	8′ 0″ 6′ 0″	All lamps	200	240	2.4	1.20	2.0	On table
Solicitors' room, second floor	10 1-lamp pend. 2-gl. N.	11′ 3″	All lamps	1120	1900	2.5	1.69	1.48	On table
Room 204, paymaster.......	6 1-lamp pend.	11′ 3″	All lamps	850	1500	2.1	1.77	1.18	On table
Room 205, under dept	4 6-lamp chandeliers	10′ 8″	All lamps	665	1200	2.2	1.81	1.21	On table
Room 303, office	1 5-lamp chandelier	8′ 0″	All lamps	240	250	2.0	1.04	1.92	On table
Room 308, office	1 3-lamp chandelier 1 100-w. tungsten	8′ 0″	All lamps	260	250	4.4	.96	4.40	On table
Room 311, office	4 6-lamp cluster 50-w. Gem	9′ 0″	All lamps	575	1200	3.1	2.09	1.48	On desks
Hallway, third floor	12 1-lamp pend.	10′ 0″	All lamps	1300	1500	.7	1.15	.61	On floor
Room 405, acct. dept..	192 20-cp. Gem ceil.	11′ 0″	All lamps	2860	9600	8.0	3.35	2.39	On desks
Room 501, president's.......	4 1-lamp ceil. 1 3-lamp ceil. bowl 1 100-w. tung. in bowl 6 16-cp. around bowl	10′ 9″	All lamps	430	800	3.4	1.86	1.83	On table
Room 600, library	4 6-lamp cluster	12′	All lamps	715	2400	3.3	3.36	.98	On table
Room 603, assembly room...	6 7.5-amp. arc lamp	25′	All lamps	2080	4800	2.8	2.31	1.21	On table

LIGHTING IN THE ROGER WILLIAMS BUILDING.[1]

BY ARTHUR J. ROWLAND.

The Roger Williams Building is a seven story store and office building, just erected at the northwest corner of Seventeenth and Chestnut Streets, Philadelphia, and occupying a lot 44 ft. x 118 ft. It has a steel concrete framework, and fireproof construction throughout. The ceilings are plaster on wire lath; generally furred down from the concrete slabs. The partitions are of hollow terra cotta tile. The first floor is the book store of the American Baptist Publication Society; the basement is their stock room and shipping department; on the second floor the officers of the company have their quarters, and at the rear there is an assembly hall about 40 feet square; the third to the seventh floor inclusive are rented to tenants,

No steam plant is installed in this building except for heating. Energy for passenger and freight elevators, pumps, and necessary motors for machinery, as well as for lamps, comes from electric service over central station mains. The lighting contract with the Philadelphia Electric Company calls for the installation of at least 1000 16-cp. lamps, or the equivalent. The electric lighting throughout the building is done by the aid of prismatic glass shades. The building is piped for gas throughout. All electric wires are carried through iron conduits, laid for the most part in the same place as that used for floor sleepers.

Since the building faces on three streets, no trouble at all is experienced in securing ample daylight illumination. The light for the store is secured through the large window space available above the show windows of the first floor, so that for the greater part of the year during business hours no artificial light whatever is required.

OFFICE AND CORRIDOR LIGHTING.

The problem which the architects set themselves in arranging

[1] A paper presented at a meeting of the Philadelphia Section of the Illuminating Engineering Society, November 20, 1908.

lighting for the building was to plan so that in case subdivision of rooms should later be made, it could not happen that difficulties would arise in the lighting of the subdivided rooms. At the same time they sought to plan so that as little expense as possible might be put into the distributing system for lighting.

The majority of offices in the building are 18 ft. x 24 ft., the shorter dimension being along the outside wall. Two ceiling outlets were placed on the long axis of the room 12 ft. apart, and one plug receptacle was placed in the baseboard on each side of each office. Referring to the ceiling outlets, the specification calls for "Gang switches for two sets of buttons for these lamps each button must control three lamps at each outlet of a given office." This arrangement was made so that in case of subdivision of rooms to 9 ft. x 24 ft., one switch would control the lamps for each room; two 3-lamp fixtures are used in each, the partition wall running below the outlets originally installed. On the corridor side of the office (the 18-ft. side) there are four transoms, the door going under the second one so that, in case of subdivision, entrance to both offices may be secured without changing the entrance. The intention was to provide switch control which would answer for either the large office or the two small ones, as might be required. This plan has been partially defeated by the particular swing given the office door, and, where subdivision has been made, a special switching device has had to be provided for one of the offices.

In planning the office fixtures, keeping in mind the above matters, it was decided to use 3-lamp fixtures, each carrying a 100-watt Gem lamp with a prismatic shade. In case of subdivision of offices the same fixtures should be used, the lamps being changed to 50-watt lamps, and shades to a proper size. The second reason for choosing this arrangement of fixtures lies in the fact that had six 16-cp. lamps been used in any ordinary fixtures, the illumination on the working plane in the office would have run between the limits of 2.5 ft.-candles under the lamps to scarcely more than 0.5 ft.-candle at the side wall. While with 100-watt lamps and shades the illumination runs about 4 ft.-candles under the lamps and nearly 2.25 at the side

walls, reflection from the walls not being counted in either case. Considering the fact that in most offices the most important lighting is at desks which are along the sides of the room, this arrangement of fixtures was considered best, even though the illumination is after all strongest in the middle of the room where it is of little account.

In the corridors prismatic shades were used on 100-watt lamps, the reflector being frosted, partly on account of the distribution of the light secured, and partly since a small fixture with only one socket was required in locations where otherwise two sockets would have been made use of.

In the corridors and offices the lamps were in all cases kept close to the ceiling, the height being 12 ft. on the third story and 9 ft. on other floors.

In the upper floors of the building a neat arrangement has been used in handling the distribution system. On the dark side of the building—away from Seventeenth Street—and on the outer wall opposite the stairway is the stack from the heating boilers; next it—coming toward the corridor—is a pipe-well for steam, gas, and water pipes; next to it, and opening from the corridor on each floor is a small closet, through which closet access is secured by a second door to the pipe-well. As one opens the door of this closet from the corridor, he finds against the left wall telephone-cables and distributing boxes. On the right wall is the conduit for the general electrical distribution in the building and the panel board of simple construction with plain iron door to control the circuit distribution of that particular floor. This method of construction makes the distributing system very accessible, hides the distributing boards and panel board from a location otherwise conspicuous along the corridors, and makes it possible to do a large amount of the kind of work necessary in the routine operation of the building without in any way coming to the attention of the tenants as they pass through the corridors.

ASSEMBLY HALL LIGHTING.

The assembly hall, already mentioned, is finished without any attempt at ornate or unusual features. The lighting is done by lamps used with prismatic shades, the fixtures being set

quite close to the ceiling. It had been planned to use 6-lamp ceiling fixtures and some side brackets, two of the brackets flanking the platform. These two last named were omitted and 3-lamps fixtures with the lamps already mentioned placed at the points where outlets had been installed.

The illumination is not quite so high as might be desirable, but the wires are as heavily loaded as the rules of the Code will permit. With high efficiency lamps it will not be difficult in the future to increase the illumination.

BOOK STORE LIGHTING.

The book store occupies the first floor of the building. Along the side and at the end a mezzanine floor or gallery is introduced. The 18-ft. ceiling of the main store permits this arrangement with a ceiling height of 8.5 ft. beneath the mezzanine floor and 9 ft. above it. The width of the main store, inclusive of the space occupied by the mezzanine, is about 26 ft. The lighting fixtures are placed on 10-ft. centres across this space and on 18-ft. centres in the other direction, this last distance being dictated by the arrangement of the ceiling panels. The special object in view was so to arrange the lighting that fairly uniform illumination might be obtained and at the same time a customer would not cast his shadow over the goods he was inspecting at a book shelf or at the display tables. In the main store an illumination of from 3.5 to 4 ft.-candles was planned to be secured by either gas or electric lighting. The room has an 18-ft. ceiling and it was desired to avoid a large expense for light, and at the same time to hold a spacious appearance in the room. This last requirement would necessitate fixtures close to the ceiling, in which position of course the largest consumption of electric energy or gas would be necessary to produce the desired illumination. In making the computations necessary it was found that if the lamps were placed 3 ft. from the ceiling a very slight additional expense would be incurred in operating them above that which would be found if they were 6 ft. from the ceiling. This result is due to the fact that with lamps higher from the floor the loss in illumination immediately below a fixture is fairly well made up by the additional light delivered

from other fixtures in the installation. It was, therefore, decided to place the lamps 3 ft. from the ceiling, or 15 ft. from the floor. The lamps are Gem units with appropriate prismatic shades, five being in use on each fixture. The electric power used is about 3.1 watts per square foot of floor surface. Each fixture also contains five Welsbach burners in 5-in. sand-blasted globes. By this arrangement it is difficult to distinguish between gas and electric light when the fixtures are not lighted. Since it is never expected to use both kinds of lighting at once, difference in color of light is of small importance.

With the gas lamps placed so high, special means are necessary to turn them on and off. Fixtures are therefore controlled in two groups by cocks in the supply pipes, these cocks being located in a convenient place on the mezzanine floor, where also is found a jump-spark gas-igniting equipment. Every gas burner is equipped with the necessary sparking device, and as an extra precaution, is entirely insulated from the fixture by a porcelain piece 2.5 in. long, which is concealed by a spun ornament on the fixture. In case it should happen that on an individual fixture a mantle should burn out or some accident make it desirable to turn off the gas there, a main plug cock is installed at the lowest point of the fixture which can easily be reached from the floor of the store.

On the mezzanine floor lamps were placed to fall into line with those in the main store and to give abundant light for book-keepers and clerks' use. Four Gem lamps are used in each fixture and two Welsbach burners. The lamps are installed 18 in. from the ceiling, so that products of combustion will make no marks on the finished ceiling while the pilot burner arrangement enables the gas to be ignited by pull of the chain whenever desired.

Under the mezzanine floor the low ceiling made it impracticable to install gas burners and therefore the fixtures are placed very close to the ceiling and equipped with 2.5-in. spherical frosted incandescent lamps.

STORE WINDOW LIGHTING.

The store windows are lighted by regular show-window reflector lined with mirror glass, in which are installed 20-cp.

Gem lamps on 8-in. centres. Reflectors have been installed only along the outside line of the windows with the purpose in view that by such arrangement it would be impossible for anyone to stand on the sidewalk and see any part of a reflector or any bare lamp. The lamps are arranged on two circuits so that on ordinary evenings half illumination may be used. The amount of illumination in the windows has not been determined. The arrangement used was the result of experimental work with various methods; comparison being upon a basis of equal watts per foot, and cost of installation. The window design was made without reference to placing lamps in it. This has made it impossible to locate the reflector so that it would be inconspicuous. In order to conceal the lamps and yet save the cost of a valence, the window curtains are kept lowered about 15 in., except when the windows are being washed. Later a deep valence will be installed in corner windows so that an observer looking in from Chestnut Street will not see the lamps on the Seventeenth Street side, or vice versa.

LAMPS AND FIXTURES.

The lamps in use throughout the building are such as are furnished on a free renewal basis by the Philadelphia Electric Company. However, the fixtures have been so planned that it would be an easy matter to change the equipment to more highly efficient lamps, should the change seem warranted, at any time in the future.

The fixtures in the building were designed by the Horn and Brannen Mfg. Co. to the specifications of the illuminating engineer. The architecture of the building, particularly in the store, was Elizabethan, and the fixtures were designed to be expressly in agreement with this style. The fixtures have shown a high order of excellence both from the artistic result achieved and the mechanical methods used. Office fixtures were finished to match the building hardware; toilet room fixtures to match the fittings there; and main store fixtures made especially to agree with the architectural style.